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# REPORT ON THE UTILISATION OF THE RIVER MURRAY, SOUTH AUSTRALIA.

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SOUTH AUSTRALIA.

# MURRAY RIVER WATERS.

# REPORT

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TO THE

## HON. THE COMMISSIONER OF PUBLIC WORKS

ON THE

# UTILISATION OF THE WATERS OF THE MURRAY RIVER FOR NAVIGATION AND IRRIGATION

AND FOR THE

# Development of the Resources of the River Valley.

By STUART MURRAY, M. Inst. C.E.,

*Chevalier du Mérite Agricole, &c., &c., &c.*

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# MURRAY RIVER WATERS.

## *PRECIS* OF REPORT.

1. Proposals have been, from time to time, advanced for the construction of navigation works on the Murray River, and the consideration of these forms one of the leading subjects dealt with in the report. In opposition to the claims herein of this State, it has been alleged that the further extension of works of this class, especially in the United States of America, has practically ceased. But, that there is little warrant for the allegation appears from the fact that works, for the canalisation of the Ohio River, in Pennsylvania, have just been completed, rendering that river navigable for a length of 967 miles; whilst a system for the canalisation of the great Kanawha River, in West Virginia, is also in progress.

2. By the report, a system of navigation works is proposed for the whole of the Murray River, from Lake Alexandrina to some miles above Wentworth, a total distance of 485 miles; to be eventually extended as far up as Echuca, on the main stream, and Hay on the Murrumbidgee. To initiate this project, it is recommended to carry out the Lake Victoria storage scheme, as put forward by the Royal Commission of 1902. It is shown that the effect of this would be to raise the level of the river, at the eastern boundary of the State, by two feet, for a period of nearly four months in each year. The cost of that portion of the works within South Australia is estimated at £483,000. The Lake Victoria works are estimated at £165,000; which latter sum is to be provided, in equal instalments by the three riverine States.

3. The construction of a barrage, as at one time recommended, for the exclusion of sea water from the lakes at the Murray mouth, is not concurred in by this report; the great loss of water, by evaporation, it would entail, is held to be a fatal objection. There is proposed, by way of substitute, a barrage across the arm at the head of Lake Alexandrina, about eight miles below Wellington; with a condition that a sufficient supply of water be sent down the river, to maintain freshness within this reduced area. It is clearly shown that, unless this be done, and the system of locks be carried down to this point, the lower Murray will, as the result of diversions higher up, become permanently salt. The cost of this work should be borne by the upper riverine States, which alone will benefit by the diversions.

4. A recommendation is made in favor of a sea level canal, from Goolwa to Victor Harbor, to carry the river traffic down to the ocean; the estimated cost being about £470,000. But this work is proposed to be held over pending the development of traffic, which will be provided for meanwhile by the Goolwa to Victor railway.

5. The reclamation of Lakes Albert and Alexandrina is shown to be quite within the limits of feasibility. It is not however recommended that this be undertaken at present; but held over to meet a future demand for land for settlement. It would add nearly 200,000 acres of land, mostly arable, to the area of the State.

6. It is proposed to initiate a system of domestic and general water supply, for those rural districts where that now available is of inferior quality, or is liable to become deficient in quantity in seasons of drought. Suggestions also are made for the improvement of the quality of water supplied in provincial towns.

7. The land about Lake Bonney, where it had been proposed to establish an irrigation settlement, is deemed specially suitable for the purpose as to a part of the area only. It is however proposed that the lake site be reserved as a storage, in which to impound water for the irrigation of the lands included in the "Lake Bonney Scheme," should these prove suitable under practical test conditions; otherwise for the service of suitable lands in the valley below.

8. The Parcoola proposed reservoir site is not considered specially adapted for purposes of water storage. It is not absolutely condemned as unsuitable; the report is rather to the effect that the facts are not sufficiently known; but that so far as they are known they are unfavorable. It is possible that further exploratory survey may place the question in a more favorable light. The paucity of economical water storages in South Australia seems unquestionable; there is deficiency of both available holding space, and facilities for economical construction.

9. If sufficient water storage cannot be secured at reasonable cost, in South Australia, it may be worth while to consider whether arrangements can be made with the upper States, for a partnership agreement, in respect of storages to be constructed there.

10. It is shown that South Australia has an unquestionable claim to a supply of water from the Murray, for the domestic, stock, and general needs of an extensive area of dry farming land; for the irrigation, to a depth of 24in., of 625,000 acres of culturable land; and for a sufficient volume to provide for the navigation of the locked river, and to maintain freshness in the channel as far down as the barrage below Wellington—a total of 88,530 millions of cubic feet per annum, for all purposes, when the scheme of canalisation is complete.

11. To meet the recognised difficulty of establishing irrigation, as an integral part of the system of rural economy of this State, it is proposed that a select number of Australian youths shall be sent, by the Government, to study the methods and appliances in use, in countries where it is practised, in preference to introducing immigrants from those countries, to practise irrigation here.

February, 1910.

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# MURRAY RIVER WATERS.

## EXCERPT FROM LETTER OF INSTRUCTIONS.

South Australia: Commissioner of Public Works' Office, Adelaide, July 23rd, 1909.

Stuart Murray, Esq., M. Inst. C.E.

Dear Sir—I accept, for the Government of South Australia, your offer to place your professional services at the disposal of this Government for the preparation of a report on the River Murray waters question, in so far as it affects South Australia; and I give hereunder some particulars of the special aspects of the question on which a report is desired.

[Memorandum for the guidance of Stuart Murray, Esq., M. Inst. C.E., &c., in reporting to the Government of South Australia on the Murray River, having special regard to the utilisation of its waters for navigation and irrigation, inclusive of a scheme of locking by weirs and navigation locks, and with special regard also to the utilisation of the lands and development of the resources of the Murray Valley and lands adjacent thereto under irrigation.]

1. The examination and report to cover a consideration of the whole of the River Murray and Lakes, from the boundary to the sea mouth of the Murray; also to include the consideration of the effect of what is known as the Lake Victoria scheme of storage; and consideration of the general subject under the following headings incidental thereto.

2. An analysis of the statistics of the quantity of water, in cubic feet per minute, monthly aggregate in cubic feet, and depth respectively, which the River Murray has discharged into South Australia in the past, so far as the records go; with the periods annually during which navigation was possible over the South Australian part of the river, by present steamers.

3. The periods of low river, with quantities and depth of water, and their effect on navigation, irrigation, and the lakes.

4. The quantities of water in cubic feet per minute, and depth, with the river in its present natural state, required to flow between (say) Mildura and the boundary, to allow of navigation with present steamers being continuous over this part of the river, and the periods annually in which navigation has been possible in the past.

5. The benefits which would accrue to South Australia from a storage scheme at Lake Victoria, as formulated by the Royal Commission on the River Murray Waters.

6. Full consideration, in all its aspects, of a scheme of locking, by the construction of weirs and navigation locks, on the portion of the Murray from Lake Victoria to Lake Alexandrina; the sites and nature of the engineering works best suited for such purposes, with general designs and the estimated cost thereof; and, in this connection, the quantity of water in cubic feet per minute, and annual aggregate in cubic feet, which would be required to keep the weirs and locks fully and permanently efficient; allowing for loss by evaporation and soakage; and allowing also for the quantity of water required to pass down over the lowest weir and lock to serve (*a*) the river below such lowest lock, (*b*) the lakes.

7. The question of storages, other than ordinary navigation weirs and locks, over any part of the river in South Australia.

8. The effect on the low-lying lands in the river valley in South Australia of the backing up of the water by storages or weirs and navigation locks.

9. The utilisation of the River Murray waters for irrigation purposes, in South Australia (*a*) on the low-lying lands in the river valley, (*b*) on the high lands adjacent to the river valley.

10. The best method of getting the water to the lands, and distributing the water, with the quantities required per acre per annum, and the estimated cost; with a description of the most desirable pumping plants for localities where pumping is necessary.

11. The effect of soakage of brackish water over certain parts of the river, at times of low water.

12. Particular attention to be devoted to the lower river between Blanchetown and the lakes, in view of the improvements which the South Australian Government has carried out, by the construction of embankments, &c., to reclaim the low-lying lands, and render the same available for irrigation. The ensuring of a sufficient and satisfactory supply of fresh water for the irrigation of such lands, and other similar lands on the lower river to Wellington, and for the town waterworks at Murray Bridge.

13. The

13. The report to cover full consideration of the question of the Lakes Alexandrina and Albert, and the problem of how the sea water can best be kept from affecting the River Murray; and how far it is expedient and possible for the sea water to be kept from entering the lakes, and the best means and estimated cost of carrying out any scheme for such purposes; or for the reclamation of any portion of the said lake beds, if such is considered practicable and desirable.

14. Careful consideration to be given to the question of a sea-level canal from Goolwa to the sea, and the estimated cost thereof.

15. And, generally, Mr. Stuart Murray's report to deal with any other important aspects of the River Murray waters question which may arise out of the investigation, and particularly any other points the consideration of which is desired by the Government. The plans and general engineering designs necessary to explain and illustrate the report to be included therewith, and to include a typical design for a weir and lock.

L. O'LOUGHLIN, Commissioner of Public Works.

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# REPORT.

To the Hon. L. O'Loughlin, M.P., Commissioner of Public Works of the State of South Australia.

Sir.—Pursuant to your letter of instructions, I have the honor to present the following report:—

1. The chief purpose of the examination, called for by the Minister's instructions, may be succinctly stated as an inquiry into the utilisation of the river (I.) as a highway of trade, and for the transport of goods, especially of the produce of the lands of the river valley (*a*) as an open channel, subject to no special control, (*b*) as a canalised channel, regulated by weirs and locks, and other navigation works; (II.) as an agent, by the economic application of its waters, for the promotion of agricultural and pastoral settlement, and for the supply of the domestic wants of the dwellers in the river valley, and the needs of their cattle depasturing therein. Subsidiary to these are the conservation of existing interests in the lower river, between Blanchetown and the lakes, and in the lands adjacent thereto; proposed reclamations in the lake beds, and the possible utilisation of the reclaimed areas as sites for settlement; and the construction of a sea level canal, or other work, to enable river-borne goods to be carried to ocean-going vessels in furtherance of foreign commerce.

## NAVIGATION.

2. South Australia has, from the initiation of the Murray River traffic, been a strenuous advocate for its continuance, development, and extension. In this matter her ambitions—possibly her interests—are in a measure at variance with those of the other Riverine States. For this reason, above all others, it is important that some understanding should be arrived at, as to the respective State rights in the control of the river waters. The uncertainty of the effect of decisions on the questions involved—there being no body of settled law applicable—renders it inadvisable, even if it were possible, that they should be considered on a legal basis only. A principle, however, that must underlie any satisfactory or enduring settlement is thus enunciated in the report of the River Murray Inter-State Royal Commission, 1902—"The conservation of existing interests, especially of such as have grown out of the natural conditions of the country of their birth, and have remained for a length of time unchallenged, is a fundamental principle of law, no less than of the public sense of justice and right, among all civilised communities." It cannot be gainsaid that the navigation of the Murray and its tributaries, from the mouth to Echuca, in Victoria, and to Hay, Balranald, and Walgett, in New South Wales, has become established by the natural conditions of the case, and has remained for many years unchallenged. The volume of the traffic in recent years will be best explained by the following statement, compiled from returns officially supplied by the railway authorities of the several States:—

| To Ports in— | 1904. | 1905. | 1906. | 1907. | 1908. |
|---|---|---|---|---|---|
| | Tons. | Tons. | Tons. | Tons. | Tons. |
| New South Wales | 7,687 | 8,793 | 10,508 | 10,371 | 10,637 |
| Victoria | 56,924 | 66,415 | 70,351 | 96,991 | 65,235 |
| South Australia | 20,638 | 19,964 | 26,641 | 25,001 | 28,042 |

Particulars were also obtained from several owners of river craft of the length of time, in each of the years 1886 to 1908, during which the rivers had been actually navigated by their boats, as follows:—

| Year. | George Ritchie, Owner. | A. H. Landseer, Ltd., Owner. | Geo. Ferguson, & Co., Owners. | Year. | George Ritchie, Owner. | A. H. Landseer, Ltd., Owner. | Geo. Ferguson & Co., Owners. |
|---|---|---|---|---|---|---|---|
| | Months. | Months. | Months. | | Months. | Months. | Months. |
| 1886 | 5 | 5 | 6 | 1898 | 8 | 8 | 9 |
| 1887 | 12 | 12 | 12 | 1899 | 7 | 7 | 7 |
| 1888 | 12 | 12 | 12 | 1900 | 8 | 8 | 8 |
| 1889 | 7 | 7 | 8 | 1901 | 6 | 6 | 7 |
| 1890 | 12 | 12 | 12 | 1902 | 1 | 1 | 1 |
| 1891 | 12 | 12 | No record | 1903 | 6 | 6 | 7 |
| 1892 | 10 | 10 | " | 1904 | 12 | 12 | 12 |
| 1893 | 12 | 12 | " | 1905 | 7 | 7 | 8 |
| 1894 | 12 | 12 | 6 | 1906 | 7 | 7 | 8 |
| 1895 | 12 | 12 | 12 | 1907 | 8 | 8 | 12 |
| 1896 | 11 | 11 | 12 | 1908 | 6 | 6 | 8 |
| 1897 | 6 | 6 | 6 | | | | |

For the greater part of the time stated the navigation was carried on by vessels of 7ft. draught; for the remainder by boats of from 3ft. to 4ft. draught. The near agreement of the returns with one another constitutes some confirmation of their general accuracy. Their consistency with the depth of water in the navigable channel of the Murray is the best confirmation possible. (See diagram, sheet No. 1, and the navigation lines thereon.)

3. Turning

3. Turning again briefly to the treatment of the subject of navigation, in the report of the Royal Commission of 1902, the following may be quoted:—"At the Renmark Irrigation Settlement the fruitgrowers suffer considerable annual loss owing to the river being closed at the time their perishable fruits are ripe. . . . One of the principal settlers said that, if the river had been navigable in June, which it was not, about 500 cases of oranges per week would have been sent away. It was also stated that at the same time there were from 250 to 300 tons of fruit river-bound at Renmark." The loss entailed on the Renmark settlers by the closure of the river navigation, at the period when their perishable fruits are in the most saleable condition, forms a strong argument in favor of rendering the navigation perennial by the construction of works for the creation of permanent slack water in the channel. As matters now stand the liability to have the navigation closed at any time without notice is an ever-growing difficulty; and it is one to remove which those interested in the river trade cannot too soon devote their best attention and their most strenuous endeavors. The permanent navigability of the river would be immediately followed by the enlargement and extension of traffic thereon.

4. In the course of the discussion that has given rise to this inquiry, and of the contention between the States as to the priority to be accorded to the several competing interests involved, it has been maintained that the continuance of river navigation is a matter of no public concern; inasmuch as it is in process of being superseded by the extension of railways. Against this view may be quoted the following from the article on "Canals," by David Stevenson, in the latest edition of the "Encyclopædia Britannica":—"Though all efforts to improve barge-canals can never bring them to compete with railways in the quick conveyance of passengers, it is surprising to find in how many places they still command an enormous traffic in goods and minerals." In confirmation of the statement contained in the second sub-clause of this quotation, the following may be cited from an article on the same subject, by Professor Vernon Harcourt, in the 1902 edition of "Chambers' Encyclopædia":—"The enlargement and extension of canals and the improvement of rivers have been vigorously pursued by the French Government simultaneously with the development of railways; and a large proportion of the bulky goods (in the year 1882 amounting to 1,384 millions of ton miles) are conveyed by water in France. There are about 3,000 miles of canals in France, and 2,000 miles of canalised rivers, in addition to nearly 2,000 miles of open river navigation; and many of the waterways are free of toll, the costs of construction, improvement, and maintenance being paid by the State. To obtain uniformity in the principal canals, constructed at different times and under varying conditions, a law was passed in 1879 for securing eventually a depth of water of 6½ft., locks 126⅔ft. long and 17ft. wide, and a clear height of 12ft. under the bridges, along the main lines of traffic. As soon as the necessary works are completed boats of 300 tons burthen will be able to traverse all the principal waterways of France." It may be added that there are to-day 3,000 miles of canals and 4,600 miles of canalised rivers, in addition to the length of open river navigation mentioned above, in existence in France.

5. In Great Britain the case is otherwise. Of the extensive system of inland waterways in use in that country at a date not yet distant, many canals are practically wiped out; others are rapidly falling into such a condition of disrepair as to render them unpopular and almost unusable. The cause is not so much the preference of the public for other modes of goods transit as the action of wealthy railway corporations in buying up canal properties and neglecting or altogether closing the works; cheap water conveyance having proved a formidable competitor with railway freight rates. Valuable information on this subject may be gleaned from a recent paper by Mr. Saner, in the "Transactions of the Institution of Civil Engineers." It is a fact, and it is due mainly to the closing of lines of cheap water carriage, that steaming coal may be purchased on the banks of the Nile at a cheaper rate than in the manufacturing towns of the English Midlands. It would be a calamity that a like state of affairs should arise here through the closure of the natural trade highway of the Murray basin by the diversion of the river waters. There must be sought a *modus agendi* whereby the small proportion of the river volume required to maintain permanent slack water in the channel may be provided without injurious interference with paramount public needs. The provision of a water supply, ample for the preservation of health and comfort among the dwellers in the river valleys, for the needs of cattle depasturing therein, and for the promotion of intense forms of agriculture by the irrigation of suitable soils, is not inconsistent with the preservation of the established river traffic.

6. In the United States of America, where but recently there was great activity in the canalisation of rivers, the work is at present carried on less vigorously. The chief causes seem to be the lowering of railway freights through the excessive competition of companies, furthered to some extent by the writing down of capital; and the extensive appropriation of public streams by the promoters of irrigation and land companies. That it is not entirely suspended is, however, evident from the following extract from the proceedings for the year 1908, of the American Society of Civil Engineers:—"The recent completion of a series of locks and dams on the Ohio River creates, with existing improvements, a navigable depth of 9ft. between Pittsburg and Beaver, a distance of 30 miles. The Ohio River is formed at Pittsburg by the junction of the Monongahela and Allegheny rivers; its total navigable length is 967 miles, and in the first stretch of the river between Pittsburg and Beaver the slope is 15in. per mile. The maximum recorded discharge at Pittsburg is 439,000 cubic feet per second"—fully seven times the greatest recorded discharge of the Murray at Morgan—"but it varies very greatly, necessitating a system of dams with movable tops. There is a large traffic on the river with barges, which are about 26ft. wide and 175ft. long. These are made up into batches of about 50 or 60 boats, towed by stern-wheel steamers, which are exceedingly efficient for the work owing to their manœuvring capabilities. After a short review of the various schemes which have been proposed for maintaining a navigable channel, the author describes the system of movable dams. The plan ultimately adopted was that of Major Morrill, which provided for 13 locks and dams between Pittsburg and Wheeling, for a minimum depth of 6ft., the dams to be of the movable type with navigable passes 400ft. wide, to be closed with Chanoine wickets and high and low weirs; also for high and low weirs, to be closed with either Desfontaine wickets or Brunot gates. The lift of the dams planned has been limited to about 8ft. as a maximum, which was based on the experience of French engineers. The wickets used in the Chanoine dams are 3ft. 9in. wide and are spaced 4ft., thus allowing 3in. spaces between them. When the discharge of the river is very small, wooden needles are used to cover the spaces between the wickets."

7. As

7. As basis from which to discuss the proposed reconciliation of the interests of trade and navigation, on the one hand, with those of agricultural production and settlement, on the other, the first requirement is a clear and explicit statement of the ascertained volume of the river, and of the dimensions, capacity, and condition of its channel. The discharges of the Murray, set out in tables I., II., III., and IV., accompanying this report, are at Mildura, at the eastern boundary of South Australia, and at Morgan—at Mildura, the lowest point on the river within the State of Victoria at which discharges have been gauged, special reference also being made to it in the instructions issued for guidance in this inquiry; at the eastern boundary of South Australia, because the volume passing there must be a governing condition in any inter-State agreement to which South Australia can become a party; and at Morgan, the lowest point on the river channel at which there are continuous gaugings.

8. The first three tables give the average volume of water flowing in the river channel for each month of each of the 23 years, 1886 to 1908 inclusive, at the points mentioned. Table I. gives the average in cubic feet per minute, for each month, of the actual measured volumes of the stream, and is exclusive of that pumped or otherwise withdrawn from the river for use at the settlement; the total for the month in millions of cubic feet, the larger unit being here adopted chiefly to facilitate condensation of the figures; and the mean depth on the navigable channel bed, or, more strictly, the depth on the channel bed due to the mean volume of flow. That the actual volume varies from day to day, and even from hour to hour, is unquestionably true; but experience shows that, for the practical purpose of a statement for discussion, the mean for the month is more convenient and more readily apprehended than would be the daily or any less volume. The labor involved in the more elaborate statement would also be 30 times greater; which consideration alone puts it out of the question. What is meant by the depth on the navigable channel bed will be explained further on. Table III. relates to Morgan. For reasons that will presently appear it is necessary to deal with it before Table II. It also gives the average in cubic feet per minute, for each month, of the actual measured volume of the stream; the total for the month in millions of cubic feet; and the depth on the navigable channel bed due to the mean volume of flow. Table II. relates to the volume flowing in the river channel at the point where it crosses the eastern boundary of South Australia. The figures in this case are the result, not of measurement, but of computation. There are no actual gaugings at this point nor any fixed gauge staff nearer than at Renmark, some 50 miles lower down the river; it is necessary therefore to explain how the computations were made. In his evidence before the Inter-State Commission, at page 141 of the published minutes, Mr. Ettore Checchi is reported as follows:—"Q. 3858. You had to ignore the Murrumbidgee, the Wakool, and the Darling?—Yes; I computed the flow. As an instance I may say that the quantity recorded as passing the Murrumbidgee at Hay, and the Murray at Echuca, is in some cases less than the quantity given as passing Mildura, which is impossible. · · · Q. 3859. How do you explain the discrepancy?—Either the Mildura, Morgan, or Darling gaugings are incorrect. I took the Mildura gaugings personally, and consider them reliable. The gaugings at Morgan appear to be correct. Morgan is a good place to take gaugings at, whereas I do not think Wilcannia is. Again, in time of flood an officer cannot reach Wilcannia from Sydney within a week, and by that time the flood may have subsided." Mr. Checchi gave a tabular statement of the discharges of the Darling, as computed by him, for the whole of each of the years 1887 to 1901 inclusive. These were accepted by the Commission, and have been here adopted. The Mildura discharges were reduced by a coefficient having a value equal to three-fourths of that derived from the experience of losses in the upper river, to make them representative of the volumes reaching the Darling junction. To these were added the Darling discharges, as above explained, and the sums equated to those at Morgan, to determine the coefficient expressing their relation. This was found to be practically identical with that denoting the proportion of losses to total volume in transit, as derived from the gaugings above. To complete the table, the volumes at the boundary for the years 1886 and 1902–1908 were then obtained by applying this coefficient to the recorded Morgan discharges for these years, with the proper correction for the actual length of channel from Morgan to the boundary. The method adopted for determining the discharge of the river at Mildura and Morgan, the points where the actual measurements have been made, is based upon that described in "Hydraulics of Great Rivers," by J. J. Révy, London, 1874; and employed by the author in the determination of the volume of the LaPlata. It is given in some detail in the "River Gaugings" compilation, 1905, issued by the Victorian State Government.

9. The volumes expressed by the figures tabulated are also represented graphically in the drawing, sheet No. 1. To enable a clear idea to be readily formed of their signification, lines have been drawn on the diagram indicative of the level of water surface at each of the three points dealt with; the levels represented being those due respectively to a depth of 6ft. 6in. and of 4ft. on the navigable channel bed. The greater depth is that required to permit of barges of 5ft. draught being towed with no greater effort than in open water; the less is just sufficient to enable barges drawing 3ft. 6in. to be towed, but with greater exertion of force than would be necessary if there were wider clearance beneath.

10. By the term "navigable channel bed" is intended a plane, everywhere parallel to the surface slope of the river when carrying a navigable depth of water. This assumed plane is 1ft. 9in. below the zero of the gauge at Morgan (as might be gathered from the figures in Table III.); and if 6ft. 6in. of depth, or 4ft. 9in. on the Morgan gauge, be taken as the full navigable depth—which it would be for barges drawing 5ft.—this depth is necessary to provide 1ft. 6in. clearance over the shallow at Hart's Island. The island is about 44 miles above Morgan, and the shallow extends intermittently for a length of about 8,600yds. There are other shallows between Morgan and the eastern boundary; but this one has the least depth of water, and is therefore the governing point. The volume due to this depth, 4ft. 9in. on the gauge, or 6ft. 6in. on the navigable channel bed at Morgan, is 390,000 cub. ft. per minute, there. The equivalent at the eastern boundary is 428,950 cub. ft. per minute; the navigable channel bed has therefore been taken as 6ft. 6in. below the surface level of water, when the volume flowing there is 428,950 cub. ft. per minute. At Mildura, the navigable channel bed is about 2ft. 9in. below zero of the gauge; and the volume due to 3ft. 9in. on gauge, or 6ft. 6in. depth of water, is 274,000 cub. ft. per minute. These depths have been verified as far as possible by soundings. It should be pointed out here that in an agreement tentatively arrived at between the Premiers of the Riverine States, but not ratified, 365,000 cub. ft. per minute is provided by clause 30 as the volume, under certain conditions, to be passed on to the South Australian boundary. This is the equivalent

equivalent of about 331,900 cub. ft. per minute at Morgan, and would provide a depth of 3ft. 11in. on the gauge, or 5ft. 8in. on the navigable channel bed, at the latter point; and a clearance of 8in. only for boats of 5ft. draught over the shallow at Hart's Island.

11. The settled rule for the depth and cross-sectional area of canals, and therefore with certain limitations of the channels of canalised rivers, is thus stated in well-known engineering textbooks:—"The depth of water and sectional area of waterway should be such as not to cause any material increase of the resistance to the motion of the boat, beyond what it would encounter in open water. The following are the general rules which fulfil these conditions:— Least breadth at bottom equal to twice greatest breadth of a boat. Least depth of water, 18in. more than the greatest draught of a boat. Least area of waterway, six times the greatest mid-ship section of a boat."—"Rankine's Civil Engineering," part III., cap. iii. Again (this is from "Law and Burnell's Civil Engineering," edition 1881, page 172)—"That there should be no material augmentation of the resistance of a boat, beyond the normal resistance in open water, the breadth at the bottom should be at least twice the greatest breadth of the boat; the depth should be at least 18in. more than the draught; and the sectional area of waterway should be at least six times the greatest mid-ship section of the boat." The rule given by Professor Rankine is also quoted with approval in "Canal and River Engineering," David Stevenson, 1872.

12. Reference to the relation between the draught of boats and the depth of water in the channel that is to carry them seems called for by the provisions of clause 33 of the Bill drafted in connection with the tentative agreement before referred to. In that clause the chief consideration to be observed in the canalisation of the river is that it shall provide for navigability by vessels drawing not more than 5ft. of water. To discuss any scheme of canalisation some limit of navigability must be assumed, and it seems reasonable to take that adopted by common consent in past negotiations. On the principle laid down in the passages cited, the upper of the two navigation lines, shown in sheet No. 1, gives the depth and volume required for free navigation by vessels drawing 5ft.; the lower that for restricted navigation by barges of 3ft. 6in. draught. But these depths and volumes relate to an open, not to a canalised, river; and the difference in conditions implied must not be lost sight of. In an open river there is a current of greater or less swiftness; and generally, for the same river, varying with the volume of flow. In a canal, or in a canalised river, when the conditions are such that vessels travel in the slack water created by the weirs, there is practically no current. The resistance to the movement of vessels up stream is greater in the first case than in the second; though of course less for vessels going down stream. Professor Rankine thus states the rule for computing the increase of resistance due to current—"The effect of the current of the stream, on the load that may be drawn by a force of haulage equal to about three miles per hour, may be roughly estimated as follows:—Load drawn against current equal to load in still water multiplied by $\left(\frac{3{\cdot}6}{3{\cdot}6 + v}\right)^2$ $v$ being the velocity of the current in feet per second."—"Civil Engineering," Part III., sec. iii. Computed by this rule the load that may be drawn in still water is to that against a current of one mile per hour as 1:0·504; that is to say, the still water load is almost double of that against a current of one mile per hour for the same force of draught. Against a current of three miles per hour the load, as compared with that in still water, is as 0·203:1; that is to say, the still water load is nearly five times what may be drawn against a three-mile current by the same force.

13. The Murray, in its present condition as an open river, like most streams of slight fall in country distant from the sea, is exceedingly tortuous. In general the deep channel followed by boats plying on the river avoids projecting points and the side on which the land is salient at bends, keeping well clear of them, even where to do so involves a considerable detour. Having passed a projection, the channel makes for the concave bank, at a point from one to two and a half times the width of the *alveus* of the ordinary river, below the cape. Thence it keeps near the hollow side; or, if the reach in front be long and straight, follows almost the centre line of the stream until the current begins to be influenced by the neighborhood of another bend or projection. Personal observation is confirmed by inspection of the charts—hand-made—used by the river pilots. It agrees also with the following by David Stevenson:—"Viewed as a purely abstract question, it may be safely affirmed that a stream is most likely to follow a permanent course when directed by a concave wall. Dr. Young observes that the centrifugal force has a tendency to draw the greater portion of the water to the concave side; and thus the greatest scouring power, and consequently the greatest depth, of the stream will be found upon that side."—"Canal and River Engineering," 1872 edition.

14. While the river remains open it would be desirable, in the interests of trade, that in years of low river, navigation should be protracted, and the periods of closure reduced, as much as reasonably possible. In the report of the Inter-State Commission, 1902, attention is drawn to the feasibility of compassing this object by the execution of the Lake Victoria regulation-storage scheme. This lake is in the State of New South Wales, within three miles of the river bank, and about 35 miles in a direct line below the junction of the Darling. "It covers an area of about 30,000 acres, and is connected with the main stream by the Rufus River, through which it is fed when the Murray is high. The level of water permanently impounded by the bar is R.L. 73·00 *(i.e.*, 73ft. above the water conservation datum adopted in New South Wales), whereas flood marks show that the lake has been filled to R.L. 90·00, the storage between the two levels being 17,000 millions of cubic feet. In order that full advantage might be taken of such floods, the lake could be filled by raising the river level below Frenchman's Creek and diverting through it to Lake Victoria. It is estimated that a weir on the river would cost £80,000, and the improvement of Frenchman's Creek and the erection of embankments and regulators £4,800, or a total of £84,800. These works would make possible the storage of 22,399 millions of cubic feet, a volume which, while allowing for evaporation at the rate of 60in. per annum, would provide in times of low river 100,000 cub. ft. per minute for a period of nearly four months." Clause 22 of the tentative agreement already referred to provides for the construction of this storage with two locks on the river. Although one lock only—the upper—would be essential if the river were to remain open, it will be better if the proposal to construct works for the provision of slack water during times of low river is adopted to take both in hand at once. The cost would in that case be £164,800 instead of £84,800. The full navigation depth with an open river, referred to in clause 10 of this report, will

will demand a flow of 428,950 cub. ft. per minute at the eastern boundary of the State; the restricted depth for boats of 3ft. 6in. draught, with 6in. clearance only, 313,900 at the same point; while an addition of 100,000 cub. ft. per minute to the volume of the stream would raise the level of the surface by almost exactly 2ft., for all depths within the navigation limits. It would be superfluous to dwell upon the advantage that would accrue from the provision in a dry season of this volume from Lake Victoria.

15. At an inspection in October, 1909, the approximate discharge from the Murray into Frenchman's Creek was 90,000 cub. ft. per minute. The site adopted as that of a weir to regulate diversion into the creek is about a mile lower down than the principal natural offtake. For the control of diversions it is suitable; while from the constructional point of view, all that could be said in the high-level condition of the river is, that no serious difficulties are apparent. At the junction of the Rufus Creek—the outlet from Lake Victoria—with the Murray, there was a discharge of about 90,000 cub. ft. per minute into the river; the lake being full to the level of the natural bar. Mr. Armstrong, the manager of the Lake Victoria Station, says, however, that with a rising river the inflow to the lake generally begins through the Rufus. From the designs prepared by the New South Wales Public Works Department the following leading particulars are taken of this proposed storage :—

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|---|---|
| Length of Frenchman's Creek from offtake to discharge | 39 miles |
| Regulated surface level at offtake | R.L. 97·00 |
| Level of bed at discharging point into and from lake | R.L. 74·00 |
| Full supply level in lake storage | R.L. 95·00 |
| Fall from regulated surface level at offtake to bed at intake | 23ft. |
| Fall from regulated surface level at offtake to full supply at storage | 2ft. |
| Length of Rufus Creek from offtake to discharge | 8 miles |
| Regulated level of river below weir at intake from creek | R.L. 69·00 |
| Fall in creek | 5ft. |

16. The permanent navigability of the Murray may be provided for by the construction of a series of works for the creation of slack water in the river channel, see diagrams, sheet No. 2. The work shown—sheets Nos. 3 and 4—consists of a movable weir and lock. The lock chamber would be 150ft. by 45ft. in clear, with 16ft. depth of water on the floor, and a further 5ft. to the cope; the lift of each lock being 10ft., except those connected with the Lake Victoria works, which would have a lift of 14ft. The lower 6ft. of depth, reduced to 5ft. 6in. over the entrance and exit sills, represents the navigable depth at the head of the pool below. The proposed lock chambers are large enough to accommodate the boats and barges at present trading on the river. Eventually, with a view to economy of water, they should be reduced to 130ft. by 26ft., sufficient for the passage of barges of at least 260 tons burthen; which might be towed, either singly or in file, by stern-wheel or by screw-propeller tug-boats. The remaining width of the channel is shown as closed by a movable weir, framed of timber wickets; adjustable from a gangway, carried on iron trestles hinged to the bed by suitable gudgeons, so that they may be folded down flat during the periods of open river; the one next the abutment being housed in a chamber contrived for the purpose. The abutments, lock chamber, and platform or bed of the weir would be of cement concrete; reinforced where necessary with bars of mild steel. As a matter of fact however this design must be understood as subject to modification. The greater part of the river will, in general, be closed by a movable weir lower than that shown; that is to say, with its bed or platform higher than, but its crest at the same level as, that shown in the diagram; the high weir being restricted to the pass, to be used when the volume of water is sufficient for open river navigation. The pass would occupy the space next to the lock, and should be about 160ft. in the clear; the low weir, separated from it by a pier of solid masonry, would be of similar design to that in the pass. The sectional area of the waterway, when these movable weirs are down, should be as near the natural section as possible: in no case must the natural section be reduced to cause sensible heading. The cost of a work, in accordance with the proposed modified design, will not materially differ from that shown. Any difference there may be will probably be in the direction of reduction. The drawings—sheets Nos. 3 and 4—are to be understood as type drawings only. It is impossible to give actual drawings of any particular work, in the absence of a detailed survey of its site and of pittings or borings of the ground in the river bed and banks. In the selection of weir sites, it is hardly necessary to remark, the presence of rock at or near the surface will be an advantage, but is not an indispensable condition. They are to be preferred in a reach of some length, where the channel is well defined and not too much curved, and the lock and pass should never be in the convex side nor near a projecting headland. That they should be in the concave side, where the reach is sensibly curved, will be readily understood from the concluding sentence of clause 13.

17. The movable weirs shown in these diagrams are of the type known as the Chanoine. They have been designed, chiefly, on the model of the improvement works of the great Kanawha River, in West Virginia; a copy of the working drawings for which has been rendered available by the courtesy of the officers of the Bureau of Public Works at Washington. The general design adopted for the improvements of the Ohio River, referred to in clause 6, is of similar type; with proposals for others of the Desfontaine or of the Brunot pattern. The Chanoine type of river navigation works is that now most favored; not only in France, where it was introduced, but also in America and elsewhere. Another type, at present in general use, and likely to prove suitable for the Murray River, is the needle weir. It has the advantage of being capable of easy manipulation, by one man unassisted; but against this has to be considered the great expenditure of time involved in raising or lowering it, when the river has to be regulated. The Chanoine weir, on the other hand, is open to the objection that the wide openings between the wickets, necessary to secure convenient working, entails a loss of water that would prove serious during low river. But this difficulty may be got over by the use of suitable needles, formed with a tongue and cover to close the spaces. As there are almost no river navigation works in existence in the Commonwealth, and few officers here who have had practical experience in their design and construction, it will be advisable that the engineer to be entrusted with the preparation of the drawings for the Murray River works, should pay a visit of inspection to several of the canalised rivers of America and of the Continent of Europe, before entering on his duties. Besides the rivers mentioned above, excellent and informative examples are to be seen on the Seine, the Loire, and the Garonne; easily accessible at all times, and where a visitor may study at leisure both the design and the mode of manipulation.

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18. In the report of the Inter-State Commission the cost of a typical weir and lock is given as £100,000, and of the necessary works from Blanchetown to the eastern boundary of the State as £600,000. The New South Wales estimate for a weir at the offtake of Frenchman's Creek, in connection with the Lake Victoria scheme, is £80,000; but that is for a work with a lift of 14ft. A weir in accordance with the type drawings accompanying this report, the lock having a lift of 10ft., should be constructed for about £73,738; and this estimate includes a fair allowance for risks and for probable loss by river floods. This should not materially differ from the cost of a work such as above described, with separate weirs, in the pass and waste channel. The cost of the system from Swan Reach to the border would then stand at £482,428. But no estimates can be taken as other than approximations, until after detailed surveys and other exploratory work on a scale of minuteness greater than any now available. The most that can meanwhile be predicated is that the cost will in all probability range between £482,428 and £600,000. See Appendix V.

19. The loss of water in the river channel due to the maintenance of navigation will be best apprehended by considering it as a fraction of the volume at Morgan, the lowest point of gaugings. Table IV. is a summary of the totals for each of the 23 years dealt with in Tables I., II., and III., the Morgan volumes being given in the last column; and it should be noted that these are the actual volumes that came down the river, and are exclusive of all diversions and all losses, whether from natural or artificial causes. In the minimum year (1902) the Morgan volume was 93,274 millions of cubic feet; that for 1901, the next lowest, being more than two and a half times as great. There is reason to believe that 1902 was an abnormal year throughout the Murray basin. The Victorian gaugings at Mildura extend back to 1865; those at Albury to 1877; and at Murchison, on the Goulbourn, one of the greater tributaries of the Murray, to 1882. In 1902 the total Mildura discharge was 57,517 millions of cubic feet; in 1868, the next lowest year, it was 196,445, and in 1884 it was 200,747 millions. At Albury in 1902 the total was 39,381 million cubic feet; and in 1884, the next lowest within the period of the records, 78,697 millions. At Murchison in 1902 the total was 27,753 million cubic feet; and in 1884, the next lowest recorded there, 50,963 millions. It is evident that the discharge of the Murray in the year 1902 was the lowest during the past 45 years, and less than half that of the next lowest year; and therefore that it ought not to be considered in any analysis of the gaugings with a view to the utilisation of the river waters. Excluding this minimum year, the volumes at Morgan recorded in Table IV., are divisible into three groups, which may properly be characterised as low, mean, and high years. Of low years, those in which the total discharge at Morgan has been less than 400,000 millions of cubic feet, there have been ten; and the average total per year has been 299,102 millions; of mean years, from 400,000 to 600,000 millions, there have been five; and their average discharge at Morgan 468,335 millions; while of high years, wherein the Morgan total has been over 600,000 millions, there have been seven; and their average discharge 818,844 millions of cubic feet. The length of the river channel from the mouth at Wellington to the State boundary is 356 miles, and the average width of the wetted surface when locked will be about 10 chains. Allowing for an annual loss by evaporation of 60ins., and by soakage at the rate of ¼in. per day over the wetted surface, the total from these causes would be 15,500 millions of cubic feet for a year. The average annual loss by lockage, allowing for ten lockings per day, would be under 250 millions of cubic feet, so that the total losses by evaporation, soakage, and lockage would be about 15,750 millions of cubic feet per annum. Of this, half of the evaporation and soakage would be inevitable in most years apart from locking, and a portion of the lockage might properly be considered as compensation water. On the whole, the loss properly debitable to the adoption of slack-water navigation works will not exceed 8,000 millions of cubic feet per annum. The result may be put in tabular form thus—

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|---|---|
| Average discharge at Morgan for—Low years, 299,102 million cubic ft. . . | Nearest simple fraction expressive of losses $\frac{1}{37}$. |
| Mean years. 468,335 million cubic ft. | Nearest simple fraction expressive of losses $\frac{1}{58}$. |
| High years, 818,844 million cubic ft. | Nearest simple fraction expressive of losses $\frac{1}{102}$. |

But the minimum volume required throughout the year at the boundary, to provide for continuous navigation, will evidently be 15,750,000,000 ÷ 525,600 = very nearly 30,000 cub. ft. per minute, about $\frac{1}{119}$, $\frac{1}{380}$, and $\frac{1}{2}$ of the respective annual volumes, which will therefore be the irreducible minimum required to pass the boundary to provide for navigation. On the like basis, the losses debitable to navigation, for evaporation, soakage, and lockage on the Murray, from the S.A. boundary to Echuca, and on the Murrumbidgee, from the junction with the Murray to Hay, would be about 14,000 millions of cubic feet per annum. But, inasmuch as these losses are from the upper rivers, and therefore from volumes that do not undergo the diminution due to following the lower river channel for an average distance of 615 miles, to Morgan, the actual loss debitable to these causes would be reduced by more than one-fourth; and 14,000 millions becomes 10,500 millions. The total annual loss of water debitable to the entire system of navigation works would thus range from $\frac{1}{10}$ in a low year to $\frac{1}{78}$ in a high year, of the volume at Morgan; although the quantity actually used, measured at the points of offtake, will range between $\frac{1}{10}$ and $\frac{1}{78}$ of that volume. No account is here taken of losses from the Darling; it being understood that there is no present intention to extend the navigation works to that river.

20. The river valley from the east boundary of the State down to Swan Reach, near which is the site of the lowest of the proposed navigation weirs and locks, is throughout much of its length bounded by cliffs of imperfectly consolidated, impure limestone, frequently close to the river channel, sometimes on one side, sometimes on the other. From this point the cliffs are less frequent; the valley gradually opens out, showing wide flats, backed by hills of gentle slope, well grassed or under cultivation; the limestone, however, continuing as the surface rock. A little below Swan Reach, it is stated, the depth to the limestone bed is augmented; but there is no visible indication of the point at which this occurs. The depth in the channel increases, so that there is ample water for such boats as could clear the locks. About 14 miles below Swan Reach a sounding was tried, but at 38ft. the lead did not touch bottom. Again, a sounding was tried in the bend above Teal Flat, about 17 miles above Mannum, with a like result. Thence through Lake Alexandrina and the channel to Goolwa deep water continues. Opposite Peltallock the depth as shown by several soundings is uniformly 13ft. Abreast of the mouth of the Finniss River it ranges from 17ft. to 18ft., while

at Goolwa wharf it is over 30ft. From Goolwa the channel continues southward about 1½ miles; thence it turns eastward about 6 miles to the sea mouth, where the waters of the Murray find exit. Throughout the latter distance the ocean is separated from the channel, which is in fact a continuation of the lakes and is here from one-quarter to three-quarters of a mile wide, by a line of sand dunes nowhere exceeding a half mile in width. At several points on this spit there are apparent evidences of recent breaches by the sea. The mouth or opening is at present about 600ft. or 800ft. wide, mostly with an apparent depth of no more than 3ft. The exception is a deeper channel of a width of 200ft. or 300ft. A sounding was obtained in the channel within the sandhills, near the mouth; the depth of water there was 8ft.; the tide being near springs and about half flood. From the eastern side of the entrance the sand dunes continue eastward.

21. So far there is no question about the easy and convenient transport of river-borne cargoes; but we are now face to face with the problem of their transference to ocean-going vessels. Two solutions have been proposed—one by enlarging the opening, or by cutting a new opening through the sandhills, to enable ships from oversea to come inside and take loading from the barges; the other to cut a sea-level canal from the inland water near Goolwa to the sea at Victor Harbor. The first of these proposals has been advocated by Mr. Thos. Walker Fowler, M. Inst. C.E., in a paper published in the transactions of the Victorian Institute of Engineers. Of the second a survey and estimate have been made under the direction of Mr. A. B. Monerieff, M. Inst. C.E., Railways Commissioner, and formerly Engineer-in-Chief of this State; and an estimate by Mr. Lindon Bates.

22. The Murray Mouth canal proposal will, perhaps, be best understood by reference to Mr. Fowler's paper. He says—"Sir John Coode seems to have estimated the cost of opening the Murray Mouth for seagoing vessels at £2,000,000, and even at that figure does not seem to have been sanguine of success; whilst Mr. Lindon Bates advocated the Goolwa to Victor Harbor canal, at an estimated cost of £571,000. Mr. A. B. Monerieff, then Engineer-in-Chief of South Australia, on going over Mr. Bates's estimate, apparently considers that the work could be carried out for £473,000." And again—"It is of course impossible, from the available data, to form any reliable opinion as to the probable cost of the works here advocated; but when it is remembered that the Gippsland Lakes were successfully opened up for £126,000, it seems probable that similar works might be successfully carried out at the Murray Mouth for a sum less than that estimated as the cost of the Victor Harbor canal. In this connection an important point would be the amount of protection necessary for shipping at the entrance. To make the entrance accessible in all weathers, probably a breakwater would be required in addition to the training walls; but as Victor Harbor would always be available as a harbor of refuge, where vessels could obtain protection during rough weather, the construction of such a breakwater might be safely postponed until the trade had developed sufficiently to justify the necessary expenditure." Mr. Fowler's view is sanguine. The opening of the Gippsland Lakes entrance cannot be said to furnish a precedent of weight in the solution of this question. Neither the degree of protection there, nor probably the width, would be held sufficient by owners of vessels of the class likely to be employed in the carriage of Australian produce to the markets of Europe. The width of the Gippsland Lakes entrance is 250ft.; that proposed by Mr. Fowler himself for the Murray Mouth is 1,000ft. Moreover, it is a fact that in rough southerly weather masters of vessels in shelter inside the lakes, with cargo on board, have lain up for days rather than face the risks of getting out into open water. It has also happened that vessels from Melbourne or other Victorian ports have in like circumstances, after cruising for a length of time outside the entrance, put back to their port of departure. The wreck of vessels in attempting to pass in or out of the entrance in unfavorable weather is also not unknown. Mr. Fowler makes no reference to the necessity for a harbor where large vessels can lie inside the Murray Mouth entrance. Such a basin is obviously an indispensable part of any scheme on the lines of Mr. Fowler's project. It would have to be large enough to permit of swinging vessels not less than 400ft. in length, with a depth of at least 25ft. of water.

23. The line of the proposed canal to Victor Harbor, as surveyed under the direction of Mr. Monerieff for the purpose of an estimate, leaves the inland water about a mile south of Goolwa. As roughly designed the bed would be 7ft. below low-water level of spring tides; bed width, 50ft.; slopes in the lower 15ft. of depth, 2 : 1, above that such as the nature of the ground may warrant. From the mouth to the crossing of the road forming the north-west boundary of allotment 2360 the soil is a light loam, generally sandy on the surface, with a tendency to become clayey from the subsoil down to the level of the canal bed. It is clear of the sandhills, except for a short distance where it crosses the slope of a detached dune. From the road crossing it continues clear of the sandhills to about 2 miles 15 chains, where it enters a lagoon, the water in which is at present about 7ft. above sea level. This has apparently been formed by a watercourse, now almost obliterated, cut through many years ago, according to local tradition, by a mass of sand carried in by storm action from the sea. The canal follows the lagoon for a distance of about 50 chains, the lagoon bed being about 3ft. above sea. The cutting would thus drain the greater part of the lagoon, reclaiming an area of probably about 70 acres. From where the line emerges from the lagoon, to about 3 miles 33 chains, it follows ground similar in character to that near the Goolwa Mouth; the maximum depth of cutting being about 17 or 18ft. At about 3 miles 37 chains it crosses a ridge, the surface level at apex being such as to entail 38ft. total depth of cutting. Thence it finds its way to near the sea beach at about 4 miles, and follows as close as possible to the foot of and inside the sandhills, which here are low, to about 6 miles. In the section between 4 and 6 miles, these low sandhills form the sole protection of the canal against possible inroads from the sea; so that it may become necessary to construct some defensive works on their seaward face to prevent them being breached in severe south-west gales. From 6 miles the line turns more directly to the west and cuts across the neck of the peninsula on which Port Elliot stands. The site of the town appears to be limestone, overlying granite; but at what depth the contact occurs on the crossing of the canal line it is impossible, in the absence of borings, to form an opinion. The depth from surface to canal bed at the highest point of crossing the bluff is 84ft.—inadvertently referred to by Mr. Fowler as the height above sea level. Thence the line follows across cultivated fields to 7 miles 50 chains, where the total depth of cutting is only 17ft. 6in. Again it keeps along the coast, at times inside the railway line, at times taking up the existing site of the railway track, down to Hayborough. In this section the railway is, and the canal would be, for a length of about 30 chains, close to the sea beach and in possibly dangerous proximity to the waves

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in rough southerly weather. The deep cutting (61ft.) near Hayborough is entailed by the necessity to cut back into the sand cliff clear of the railway line. Mr. Fowler refers to the canal line, after passing the high ground at Port Elliot, as entering a valley draining to the Hindmarsh Creek. The valley referred to does not drain into the Hindmarsh. Its waters are discharged directly into the sea by a culvert in reinforced concrete under the railway line at about $7\frac{3}{4}$ miles. It is separated from the Hindmarsh Valley by a saddle, to cross which would entail a cutting, probably not less than three quarters of a mile long, and reaching at the crown to a depth of over 50ft. A distance of 12 chains after leaving the Hayborough cutting carries the canal into the channel of the Hindmarsh River, which it approximately follows a further distance of 16 chains to the sea. The total length of the canal line from the mouth near Goolwa to the termination in the open water of Victor Harbor is $9\frac{3}{4}$ miles. As to the line surveyed, it has evidently been located with care and skill. The low-water level of spring tides at the canal entrance is identical with that of gravity surface of water in the lakes; a tide lock will therefore be required at the Victor Harbor mouth of the canal. The cost of such a work, there, should not exceed £15,000.

24. It will be understood that the design is for a sea-level canal, and the question at once arises—Why not a locked canal, seeing that the cost of the cutting would in that case be so much less? The answer lies on the surface. A canal following the rise and fall of the country would have to be filled by pumping, there being no side streams of any use on the high land adjacent. The whole supply would have to be pumped from the sea at or near Port Elliot, and the continuous cost of raising water and working the locks would be too heavy a handicap. Besides, if to the cost of cutting the canal there be added that of building the locks the saving in construction would not be great. The estimate of £515,000, given by the Public Works Department, has been examined in the light of facts learned by personal inspection, the amount seems high. The leading items are—

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| Excavation in earth | .. .. .. .. | at 9d. to 1/- per cub. yd. |
| Excavations in rock | .. .. .. .. | " 3/- " " |
| Shifting railway | .. .. .. .. .. | 1 mile 7 furlongs, £16,000 |
| Bridges, road approaches, and fencing | .. .. | .. .. £25,000 |
| Protective works at Victor Harbor outlet, &c. | .. | .. .. £15,000 |
| Protecting slopes, &c. | .. .. .. .. | .. .. £12,000 |
| Land, supervision, contingencies, and interest | .. | .. .. £115,063 |

For amended estimate, £455,730, see Appendix VI. But to this will have to be added an indefinite sum for protective works at certain points on the seaward face of the dunes, lying between the canal and the ocean beach.

25. Victor Harbor consists of a partly natural, partly artificial bay, sheltered from seaward winds, and especially from the south-west, by the land on which the town stands and by the higher land behind it; by the continuation of the coast southward to Wright Island and the promontory and high bluff of Rosetta Head; by Granite Island, with its eastward extension of 1,000ft. by a breakwater of granite blocks; and by Seal Island. The protection fully covers the mouth of the Hindmarsh River and the *debouchement* of the proposed canal. The harbor has at present one timber pile jetty 300ft. in length. The depth of water at the jetty is 18ft. at the landward and 25ft. at the seaward end at low-water springs. There are also moorings for vessels in the deep water. The sheltered area includes between 250 and 300 acres of not less than 25ft. minimum depth, and is capable of indefinite extension by the lengthening of the breakwater and jetty. The bottom in the deep water is reported by the local acting harbormaster to be of limestone and mud. Granite Island is connected from its western end by a timber gangway of about 2,400ft. to the mainland at the town.

26. On a review of the foregoing, the extent to which the river would be drawn upon to provide water for the maintenance of permanent navigation appears the most important question concerning the other States. This is dealt with in clause 19. In a year of low river discharge, it would be one-thirty-seventh of the total volume for the year at Morgan; in a mean year, one-fifty-eighth of that total; and in a high year, one-one hundred and second part thereof. In the year 1902, that of the lowest discharge of the Murray during the past 45 years, it would have been one-eleventh of the Morgan discharge. But the conditions of that year were so phenomenal that, were the like to recur, the use of the river water would for the time be restricted by common consent to domestic and sanitary purposes and the preservation of valuable stock and of profitable permanent plantations. The cost of the river navigation works in South Australia would be within £600,000, of those necessary to carry the traffic to the sea within £515,000, while some reduction of the first of these amounts might be hoped for. No close or reliable estimates of these projects is possible until some general scheme is adopted and the sites of the principal works are decided on, carefully surveyed, and the ground properly explored. A detailed survey of the river channel, from the eastern boundary of South Australia to Swan Reach, including all the ana-branches, billabongs and lagoons, within the space bounded by the cliffs, has been recently carried out by the Engineer-in-Chief's branch of the State Public Works Department. The plotting of the work is approaching completion. It should prove of the greatest service in the selection of sites for locks and other navigation works. Time will be required to carry these out and to develop the river trade. Meanwhile the traffic from Goolwa to Victor Harbor may be accommodated, at a somewhat increased rate, by the existing railway. The first works to be put in hand are those of the Lake Victoria storage and regulation. This item of the general scheme, useful in connection with a locked river, would be even more so while it remains open. The tentative agreement, already referred to in this report, expressly provides that the Lake Victoria works shall be the first undertaken, that they shall be constructed by the State of South Australia, and that the cost of such construction, and the subsequent maintenance, shall be borne by the three riverine States in equal shares.—*See clauses* 22, 28, *and* 29 *of the agreement in question.* The engineer, to be entrusted with the preparation of the drawings for the Murray River works, should be afforded an opportunity of paying a visit of inspection to some of the canalised rivers of Europe and America, before entering on his duties.

## IRRIGATION; AND GENERAL WATER SUPPLY AS AN AID TO THE DEVELOPMENT OF THE RESOURCES OF THE RIVER VALLEY.

27. The subjects of irrigation, and general water supply to the settlers in the rural areas, specially referred to in paragraphs 9, 10, and 12 of the Minister's letter of instructions, are so intimately associated that they will be best considered together. In the first place, the depth of water to be applied annually to lands under irrigation, or the depth that will secure the best results from wet culture, is a prime consideration in any scheme for the utilisation of the river waters as an aid to agriculture. Victoria being the most advanced State in the establishment of irrigation under Government control, it will be advisable to consider her methods and the results. In the earlier irrigation projects the depth of water proposed to be applied to the land annually was from 12in. to 16in., wet cultivation being then looked to chiefly as an insurance against drought, to be made as widely applicable as possible. In fact, these early schemes might properly be regarded as the natural expansion of still older ones, whose aim was merely the conservation, storage, and supply of water for stock, and for the ordinary purposes of the farm and the station. Such schemes for the supply of water to the agricultural and pastoral districts had been carried out in Victoria earlier even than 1880—in some cases by the Government, in others by corporations under powers conferred by local government acts, and, for the most part, with funds advanced by the State. By the later development they became divided into two classes—those whose functions were restricted to the supply of water for domestic and general use and for stock, in what may be termed the dry-farming areas; and those supplying water for irrigation. All the corporations borrowing from the Government undertook to pay interest on the sums advanced. Of those whose functions were restricted to ordinary water supply a few have met their financial obligations in full, or nearly so. The majority have made some substantial contribution towards the discharge of their liabilities. On the other hand, the irrigation trusts have, with little exception, failed to provide interest on their loans. Bodies invested with the combined functions of water supply and irrigation have generally met the claims for interest falling due in respect of their borrowings for water supply only. In respect of advances for the construction of irrigation works, the undertaking as to repayments has remained almost wholly a dead letter.

28. Under the provisions of the law now in force—the *Water Act*, 1905—the whole of the irrigation works, and several of the schemes for domestic and stock supply, have passed under the control of the Government, as represented by the State Rivers and Water Supply Commission. One of the chief purposes of the creation of this body is that it may employ the wide powers with which it is invested to obtain for the State a revenue commensurate with its outlay, as well on works carried out by its own officers as on loans advanced in years gone by to trusts to carry out their authorised schemes. The Act referred to passed both Houses of Parliament almost without opposition—certainly without any vigorous or concerted opposition. Notwithstanding this, it has evoked considerable hostility in the districts where steps have been taken to put it in force. Under the old law landholders were free to irrigate their holdings or to leave them unirrigated, as they might think fit. Under the Act of 1905 it is incumbent on them to irrigate a certain proportion of so much of each farm as is not absolutely unfit for irrigation—or, more strictly, to pay for the water necessary therefor. Now Ministers have announced their intention to ask Parliament to invest the Government, and the Commission, with more comprehensive powers. It is proposed that in irrigation districts to be hereafter constituted the area of holdings of land will range from 20 to 200 acres, the average not exceeding 100 acres. The allotment of water to these properties is to be sufficient to irrigate the entire area of each to a depth of 24in. each year. It is claimed that by these means the best use of both land and water will be promoted, and improved opportunities given for men of limited resources to obtain homes. Where present owners of irrigable lands within such districts refuse to subdivide their properties, or to sell to the State that they may be used for closer settlement, powers will be taken for compulsory purchase.

29. In a publication issued by authority of the Government, it is stated that the aim of the new policy is to provide farms small enough to be within the reach of men who have little beyond their own industry and thrift, as well as holdings large enough to attract men of organising ability who have capital to invest. Examples are given of actual results realised on irrigated farms within the State; which, if they may be accepted without qualification, go to show that the anticipations on which the new policy is based are within the compass of possible realisation. The first case cited is of a farm of 56 acres, yielding for the past year a gross money return over £5 per acre; the second refers to a holding of 27 acres, with a gross return slightly under £4 per acre; the third, of 35 acres, returning £5 6s. per acre; and the fourth, of 17 acres, yielding for the year £18 per acre. The details of these statements seem reasonable and consistent enough with the following exceptions:—In example 1, the milk yield is valued at £8 per cow; in example 2, at £12. The former of these is well within the compass of belief; the latter unattainable, except in rare and favorable circumstances. In the fourth example the price of lucerne hay on the farm is put down at £3 per ton—a rate higher than has ruled, even in the city, except in seasons of drought. But it is admitted in the publication referred to that the demand for irrigation blocks in the areas already subdivided and offered for settlement has not realised expectations. The slackness is thus accounted for—"The sole and sufficient reason for this limited demand is that very few well-to-do Victorian farmers want to become irrigators. They wish to continue the combination of grain-growing and lamb-raising, which has proven so satisfactory outside the irrigated areas, and which requires large holdings. The opportunities of pioneer farming on large holdings of cheap land in other States are more alluring than those of intensive culture on small holdings under irrigation. The first is a continuation of what they understand; the second is a step into the unknown." It might with reason have been added that men who have after years of laborious effort found a haven of rest will be cautious in risking the fruits of the past in what the chairman of the Commission aptly describes as "A step into the unknown." There is also to be reckoned with, the unwillingness of the average citizen, presuming that he knows his business, to be coerced into substituting for his own methods those favored by authority. The change of feeling towards irrigation, especially towards irrigation under State control, ought not to excite surprise. It now presents itself under an aspect totally different from that under which it evoked much enthusiasm among the dwellers in the warmer districts of Victoria, some twenty-five years ago. Then it appeared as an insurance against the more terrible effects of seasons of drought. Now it comes as a benefit in which the older settlers will not share—as a means of planting a new race of cultivators on the soil, rather than of protecting the interests of those already established. 30. A

30. A non-sentimental difficulty that seems likely to arise in time in a settlement of small holdings, where every acre is irrigated and devoted to intense culture, is that of arranging for a systematic rotation of crops. This feature of farming is one of the most characteristic, and probably best, of the British system; and it has proved no less advantageous in the cultivation of fruit than in that of grain, flax, or roots. One of the best known and best informed writers on the wine business of France, Dr. Jules Guyot, insists strongly on its necessity in what has been from a very remote time the chief rural industry of that country. Good wine cannot be produced from immature plants, nor can heavy yields be obtained from exhausted soils. In any one of the great vineyards of this, the premier agricultural country of Europe, the area at any time actually under vines rarely exceeds about 300 acres. This is true of such properties as Chateau Lafitte, Chateau Margaux, Chateau La Rose, Chablis, Clos Vougeot, &c. At the same time the area under cultivation, worked on a system of rotation wherein the vine is a prominent element, will generally embrace 1,200 or even 2,000 acres. The point as to which opinions chiefly differ is the duration or period of the rotation, expert vignerons favoring periods varying from about 25 to about 75 years. Suppose the area of the property to be 1,800 acres, and that of mature vines still in vigorous bearing (say, from seven to seventy-five years of age) 300 acres, each plant might, under the short rotation system, occupy the same site for 20 years, under the long-period system for 60. The portion of the property not actually under vines is devoted to ordinary farming, carrying crops of grain, hay, potatoes, beans, &c., or is laid down temporarily in pasture; those crops being generally preferred that give rise to the greatest volume of farm-yard manure. It is true that the vine is not extensively irrigated in France, at least not where the production of wine is the ultimate object; except in the department of the *Bouches du Rhone*, where irrigated vineyards have largely supplanted irrigated madder fields, since madder cultivation has been extinguished by the introduction of aniline dyes. Few plants are so well adapted for intense culture as the vine; whether as an agent for the improvement of the soil, and its reduction to a high culturable condition; or for providing an assured income to the cultivator as the reward of his labor. A great step forward will be made if means can be devised of combining intense culture, especially under irrigation, with a proper system of rotation. The difficulty is a remote one, but for that reason none the less real.

31. The difficulties that have been experienced in getting Australian youths to take up the areas thrown open to selection, under the system of subdivision into small blocks, have induced the chairman of the Commission to recommend the introduction of immigrants from abroad, from the Western States of America or from the irrigating countries of Europe. A course more likely to prove acceptable to the Australian public, and not less likely to prove successful in acclimatising methods of intense culture, would be to send Australian youths abroad to learn, by seeing for themselves, the ways and practices of other countries. The cost of an experiment of this kind would be well-spent money. No high attainments or lengthy period of preliminary training would be necessary. The educational standard need aim no higher than the certificate of the State school; with the addition, except in the case of lads going to America, of so much knowledge of French, Spanish, or Italian as any industrious and capable youth might acquire in six months. The candidate for an appointment should of course be of the farming class; able to manage horses, to hold the plough, and to perform the ordinary operations of tillage. The money provision made for him need include nothing more than a steerage passage to his port of destination (his living he will be expected to earn), a sum, in the event of sickness, to be paid only on the warrant of the British consular agent in his land of residence, and after the lapse of about three years the cost of a return passage to his home. Less than £1,500 a year would be ample to cover the entire cost; and to ensure the introduction each year of six or eight lads, conversant by actual personal experience with the methods in use in countries where irrigation is the heritage of centuries.

32. Irrigation as hitherto practised in the Murray River Valley, in South Australia, is of two essentially distinct types; namely, that on the low-lying river flats, reclaimed from liability to inundation, more or less frequent, by the construction of levées, and generally irrigable by gravitation; and high-lying lands in the country adjacent to the river flats, commandable only by pumping. Some of the protective levées intended to secure these low-lying areas against invasion by the river were inspected in company with Mr. Kellett, the local officer in charge of construction. On some of the reclaimed lands there was surface water, apparently not soaking through the embankments, but from ordinary rainfall, excessive irrigation, or seepage rising in the fields where the cultivated area is below the water level in the river. There did not seem to be any difficulty in dealing with it by the collecting drains, sump wells, and pumps, provided for the purpose; nor is any other provision called for. The material used in the protective embankments is of poor quality, shrinking and compressing excessively in drying. It is, however, the best obtainable at warrantable cost. Mr. Kellett says he uses core material of semi-decomposed limestone where special bond seems necessary. The inspector relies on his own judgment solely in the selection and mode of using materials. An embankment was noticed in course of construction near Burdett in dangerous proximity to live trees. Some of these, as seen from the river, appeared to be within 30ft. of the toe of the earthwork; so near that they could not without difficulty be felled clear of the embankment, and yet that if allowed to remain their roots would be a source of imminent danger to it. Roots of growing trees are most destructive to earthworks; so much so that no live tree ought to be allowed nearer to a bank than 100ft. or 120ft. There was also inspected an area of about 1,500 acres of reclaimed land, the property of Mr. Morphett, near Wood's Point. The embankments are similar in character to those carried out by the Government, except perhaps that they are a little stouter. They have been in existence 25 years, are well executed, and in excellent order. The reclaimed land, chiefly used for growing fodder, is said to carry two cows per acre. The fertility of these river-flat lands in general is remarkable.

33. The progress made in irrigation, on the high lands adjacent to the river flats, will be best explained by transcribing the notes of personal inspections:—At Mildura, a fruit-growing settlement adjacent to the river, in the State of Victoria, founded about twenty-three years ago by the Messrs. Chaffey, the total area now under cultivation appears to be about 12,000 acres. Almost the whole is irrigated, although the depth of water used varies greatly with the season and with the kind of crop grown. During the current season the volume

volume of water used has been much below the average, in consequence of the frequent and abundant rains. The principal crops are—of vines; White Muscat of Alexandria, Sultanas, Zante currants; also lemons, oranges, apricots, olives—chiefly for oil—lucerne and other fodder plants, culinary vegetables. The present population is nearly 5,000; the annual money value of the produce grown, about £30 per acre, equal to about £70 per head of the whole resident population. Local business is good, and the place has an air of increasing permanence and prosperity. The pumping plants have recently been to a certain extent consolidated, and they have been strengthened, so that the efficiency has been improved and the cost of working reduced. The channels, with a few notable exceptions, are in good order; so also are the channel structures, generally. The same is true of the machinery.

The town of Wentworth, at the mouth of the Darling, has suffered some falling off of prosperity in recent years—chiefly by the decline of river traffic, due mainly to the diversion of the carrying trade from the rivers to the New South Wales railways. The decline, however, seems to have been arrested, and the prosperity of trade, in some measure, restored, by the increase of settlement at the irrigation colony, established some three or four miles above the town, on lands near the Murray. Time did not permit of visiting this settlement. A few facts were learned in regard to it from business people in Wentworth.

Examined the pumping plants, channels, and plantations, at the Renmark Settlement; and obtained certain particulars from Mr. Edward Olorenshaw, the chairman of the Trust. At present (4th October) one plant only is running, viz., that supplying the 60ft. channel. It consists of a compound Tangye engine of 200-h.p. nominal, driving two centrifugal pumps; a third pump is not connected. It lifts from the billabong, or backwater, known as the "Reservoir," into the main channel of the 60ft. system. This plant is in good order and condition. Other plants examined, not working, were in fair order. The channels were also in fair order. The plantations in general were weedy—in consequence, probably, of the moist season; otherwise they were healthy. The area now under irrigated culture at Renmark is 5,200 acres. There are, in addition, 550 acres of cereal crop, chiefly for hay and green feed. The water supplied to the irrigators is, according to the chairman, about 20in. per annum at the fields. The population numbers about 1,800. The principal crops grown are White Muscat, Sultanas, Zante currants, oranges, apricots, pears, olives (chiefly for oil), and culinary vegetables. The place is prosperous.

The Lyrup village settlement was founded in 1894. There were originally 40 members of the association, settlers on horticultural blocks. Of these 24, or their representatives, remain in possession. The total present population is 103. The land under irrigated culture is now about 400 acres, viz., 230 under vines; 35 other fruits—apricots, oranges, &c.; and about 135 in cereals, lucerne, and fodder crops. This comprises besides the settlers' blocks, a considerable area cultivated by the association for the common benefit. There is also a part of the land conceded to the association let for ordinary farming—some at rates as low as less than 6d. per acre, some at higher rates. Some of the plantations visited were exceedingly clean and well kept—in fact, models of high culture. The plant comprises one 25-h.p. steam engine and one 15in. centrifugal pump. The secretary, Mr. Brown, says that the depth of water applied to the plantations reaches in some years to as much as 36in. This is probably the volume pumped, including considerable loss by percolation from the unlined channels. The water charge to the settlers is 30s. per acre per annum. The proceeds of this charge, with the amount recieved as rents of land let for farming, is devoted to the cost of maintenance and management, interest on loan advances, and repayment of principal by instalments spread over 42 years.

Examined about 16,000 acres of land lying to the east, north-east, and south-east of the township of Loxton, chiefly in the hundreds of Gordon and Bookpurnong. About three-fourths of the area inspected is occupied by agricultural settlers, and a further part is in process of being prepared by intending settlers for occupation. The soil is everywhere of red sandy loam, varying in character from almost pure sand to rather stiff clayey soil. It is well-grassed throughout and timbered with open forest of box, pine, mallee, sandalwood, and undergrowth of scrub plants. The holdings near the Murray frontage are supplied with water from the river—in many cases by pumping by means of windmills, in others by carting for domestic use, the stock being driven to water. A considerable extent of the land further from the river is supplied by water drawn from bores or wells sunk to depths reaching to as much as 200ft. The water from the bores and wells, although used by stock, and even for household purposes, is not of unexceptionable quality, being generally hard, sometimes even brackish. The country, so far as can be judged by the eye, is capable of being served from the river by pumping in conjunction with a proper system of distributing channels. Of the 12,000 acres, or thereabouts, of occupied lands at least 6,000 acres is under crop. The cultivation is entirely of wheat—apparently chiefly for grain, in part probably for hay. Some of the fields show excellent growth, likely to yield 20bush. per acre. More than half would certainly exceed 12bush.; none would, unless the weather prove very unfavorable, return less than 6bush. or 8bush. The stock, both dairy cattle and beeves, are in splendid condition. The same is true of the working horses, and there are numerous fine stallions also in good flesh.

At Lake Bonney and the site of the projected Cobdogla irrigation scheme the level of water in the river on 8th October was 17ft. 6in. on the gauge at Overland Corner, and the lake was full to about that level. Examined the character of country and soil of the lands proposed to be irrigated. It consists of undulating downs, lightly timbered with box, myall, and hop bush; the ground herbage of inferior grass, with patches of spinifex. There are also small areas of sandridges timbered with pine. The soil in general is a rather stiff red loam. In some parts the subsoil is of nodular limestone. In the north-eastern and northern part of the area the country is of the character known as red mallee. This is more sandy than that above referred to, and is better adapted for irrigation, but the area is limited. Reports on this project have been printed for public information—from the surveyors' point of view, and with respect to the character and quality of soil, by Mr. W. Porter; from the point of view of the engineer, and with respect chiefly to the estimated cost of the works of storage and distribution, by Mr. A. B. Monerieff, late Engineer-in-Chief. The estimated capital cost of the works is £83,000. The storage ought, in any case, to be made available for supplementing the natural volume of the river, in much the same way as it has been proposed to utilise Lake Victoria. The supplement would in this case, however, be of value for irrigation and general water supply rather than for navigation. It will be advisable to reserve the land, the site of the Cobdogla scheme, from occupation or sale until its value for irrigation has been practically tested.

34. The depression known as Lake Bonney is also part of the site of another and more ambitious storage scheme, the PARCOOLA RESERVOIR. This is described in some detail in a published plan and report by Mr. Moncrieff. The report is by no means sanguine as the following extracts will show:—"There is only one cross section of the river available in the neighborhood of Overland Corner. This shows in some respects a suitable site for the work required, but the foundations of the weir would require to be of abnormal proportions, and the exact location cannot, therefore, be finally determined until a much more exhaustive examination of the neighborhood has been made. I estimate approximately that the works necessary at this place, as described above, would cost £210,000; but, in making this statement, I would ask the Hon. the Commissioner to note that the estimate is based upon outline sketches only, and that if a thorough examination of the neighborhood is made, as recommended above, it is probable that not only can the site be changed with advantage, but that the cost of the work may be lowered." From a careful examination of the locality without, however, any instrumental survey, the site selected appears, on the face of the matter, especially in respect of storage capacity, to be the most suitable. The cliff in the left bank shows beds of stratified impure limestone. The slope in the right bank is of the ordinary loam of the locality, probably overlying limestone, bedded, and in the form of rubble. The flat is of like character. The cliff in the left is precipitous —probably $\frac{1}{6}$ or $\frac{1}{8}$ to 1. There will be considerable cost involved in making water-tight bond here with the abutment of a structure; the like difficulty may be anticipated with the foundations. The underlying material is shown, by some borings that have been made, to consist of alternating beds of sand and sandy clay, resting on sandy limestone, with intercalated layers of soft clayey sandstone; an unpromising footing for such a structure. The barrage will, when the storage is full, have to carry a head of 40ft. of water, and be capable of safely discharging over its flood escapes a volume that must be reckoned as a possible six millions of cubic feet per minute. The local stone also is neither sound enough nor hard enough to be suitable for the aggregate of concrete. Stone for that purpose will have to be carried to the locality. Suitable sites for storage dams, in situations commanding the lands of the Murray Valley, in South Australia, are certainly not numerous within the State. They are, in fact, hard to find; and such as they are, the difficulties and consequent cost of construction is likely to be excessive. Failing suitable and economical sites in South Australia, negotiations might be opened with the Upper Riverine States to secure an interest in storages within their territories. The stored water would, of course, be sent down the river channel, to be diverted or pumped to the points where it may be required. In clause 62 of the unratified agreement referred to in paragraph 10 of this report, there occurs the following:—"Any State shall have the right to make use of the channel of any river or stream as a conduit for the conveyance of stored water to any point of diversion." It may be presumed that a like provision will be embodied in any agreement that may be arrived at, in substitution for that referred to.

35. The MURRAY BRIDGE town supply is pumped from the river into an elevated tank, from which it is distributed through pipes by gravitation. It appears liable to become more or less affected by salt in protracted periods of drought, and consequent low river. In a provincial town, with a population somewhat larger than at Murray Bridge, a like difficulty was experienced during several years, the town supply being pumped from a river, perfectly fresh during winter floods, but salter than the lower Murray, after a month or two of drought. As a tentative remedy, a tank, partly excavated and partly embanked, was constructed in what fortunately proved good holding ground, and of capacity sufficient to give a fair domestic supply, throughout the summer. The tank was filled with water, drawn from the river by means of a floating arm, from a level of less than 2ft. under the surface; stored there until the river water began to get brackish, in its lower levels; and for the remainder of the season the public supply was lifted into an elevated tank, by the same pumping plant, and thence distributed as at Murray Bridge. The method was entirely successful, and the works are still in operation. Fresh water, being lighter than salt, floats on its surface; and although there is a certain tendency to fusion, by the property of fluids known as *osmosis*, the separation remains sufficient for most practical purposes, for a greater or less length of time. A floating arm at the suction intake, raised or lowered, from time to time, according to the condition of the river water, is used in pumping the supply for the railway service at Murray Bridge. A like expedient should be adopted in the case of the town supply.

36. Pumping water from the river, whether for town supply, for irrigation, or to meet the domestic and ordinary needs of agricultural or pastoral settlers, and for the cattle grazing on their lands, should be discontinued when the stream becomes foul or stagnant. To secure the best and freshest water, it should be taken from a depth of not more than 18in. or 2ft. under the surface, and where exposed to sunlight. The volume pumped should bear a definite and uniform ratio to the population to be served, the land to be treated, or the area to be supplied. The service to an urban population, in our climate, should be not less than 40galls. per head per day in cool, moist weather; and need not exceed 100galls. in the heat of summer; except where garden irrigation is practised, in which case water should be paid for by measure. The daily demand will be somewhat larger in a manufacturing than in a purely residential town; and the maximum is usually between the hours of 6 and 10 a.m. Generally, it may be anticipated that half the daily consumption will be during those four hours. For the irrigation of land the depth will vary with the character of the soil and the nature of the crops grown. In northern Victoria a net depth of 24in. per annum has been adopted by the State Rivers and Water Supply Commission as that to be supplied to landholders in the irrigation districts; a like rule seems to prevail in South Australia. The equivalent of a depth of 24in., during the irrigating season, to the lands commanded by the channel system, with, however, a liberal margin for contingencies, is generally the normal capacity of irrigation pumping plants in this State. Where a pumped supply of water is to be delivered through channels to the holdings of settlers in the dry-farming districts, it is as essential as in the case of supplies for irrigation that the volume delivered should bear a definite proportion to the area of land served. In the State of Victoria, where a large extent of dry-farming country is thus watered, and a thriving population maintained on land otherwise almost unproductive, necessity has compelled the adoption of a regulation fixing the minimum capacity and depth of settlers' tanks relatively to the areas of their holdings—that is to say, to the number of cattle grazing thereon. The same regulation provides that water shall be supplied once only in each year This is to avoid the enormous waste entailed by sending water down channels in porous soil in hot dry weather. (Waste may be minimised by lining the channels with concrete of native lime, where this material

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is available; a method of which numerous excellent examples are to be seen in this State.) The minimum fixed by the by-law is equivalent to about 1½galls. per acre per day throughout the year—a not too liberal provision to cover use and waste. It is, however, the *minimum;* the maximum may presumably be any reasonable quantity demanded, provided there is stock on the land to use it, and there are tanks in which to store it. It would not be too much to say that the value of land, such as that inspected near Loxton, would be greatly enhanced by the provision of an assured water supply on some such basis as this. Appendix I. is a copy of the regulation referred to. Appendix II. is a copy of the Commission's by-law, No. 105, defining the amount of the rate for the year 1909-10, in the Long Lake Waterworks District. Appendix III. is a brief description of several of the principal pumping plants recently erected, or now in course of erection, by the State Rivers and Water Supply Commission. Appendix IV. is a summary of the plant and works, with their duty and cost, of the Long Lake Waterworks District.

37. Conclusions in regard to the irrigation and general water supply aspects of the Murray waters question in South Australia may be thus summarised:—

The depth of water to be provided for irrigation in settlements devoted thereto, may be fixed, tentatively, at 24in. per annum; whether on the reclaimed land of the river flats, or on the high land adjacent.

Regular and consistent rotation of crops should be encouraged under every form of cultivation, whether wet or dry, and under all conditions of occupancy.

It will be better to send young Australian farmers abroad, to study irrigation where it is practised, than to bring immigrant irrigators to Australia to teach settlers here.

There are extensive areas of dry land in South Australia, where profitable settlement might be promoted by the supply of water for domestic and ordinary purposes. The country about Loxton, described in paragraph 33 of the foregoing, may be taken as typical of a large area of country of this class. The value of such lands would be greatly enhanced by the provision of an assured moderate supply of water.

Water for domestic use, pumped from rivers or other natural sources, should be drawn by a floating arm from a depth of not more than 2ft. under the surface, and where exposed to sunlight. The purest and most wholesome water is generally to be found in this situation.

The lands embraced in the Lake Bonney projected irrigation scheme should be reserved from sale and occupation. The lake may eventually prove of value as a storage, whether the lands directly commanded should or should not prove suitable for irrigated culture.

In the event of sites for reservoirs, on a scale of sufficient magnitude, not being found available in this State negotiations should be opened, with the upper riparian States, for the conclusion of a partnership agreement, whereby South Australia might share in the use of storages therein, and in the use of the water impounded.

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## PROPOSALS FOR THE EXCLUSION OF THE SEA FROM THE LAKES AT THE MURRAY MOUTH, AND FOR THE RECLAMATION OF THE LAKE BEDS.

38. The purpose of the proposed barrage, for the exclusion of the waters of the sea from Lakes Alexandrina and Albert, and from the Coorong and others of the channels connected with these lakes, is to maintain the impounded water permanently fresh. Obviously, therefore, a necessary sequence of the construction of the barrage will be, a supply of fresh water to be sent down the Murray to make good the waste caused by evaporation. The water so sent down could not be abstracted for irrigation, or any other economic purpose; it is a necessary condition of the case that it must not be interfered with. The surface area of the lakes and channels referred to is 192,000 acres; and the evaporation from this sheet, at the rate of 60in. per annum—it is not likely to be less than this—will be 42,000 millions of cubic feet per annum. The loss of water entailed by giving effect to such a proposal would be about one-seventh of the total discharge of the Murray at Morgan, in an average low year, of which there have been 10 during the 23 years covered by the recorded gaugings. Or, again, it would be nearly one-half of the total discharge at Morgan, for the minimum year, 1902. It is hopeless to expect that the upper States would consent to send down such a volume of fresh water, in low years, to be dissipated by evaporation from the lakes; nor does it seem likely that by invoking the aid of any higher authority they could be constrained to do so. The construction of the barrage, as an engineering work, would involve no insurmountable difficulty; but the proposal to maintain the freshness of the lakes, in low years, at the cost of such a terrible consumption of river water ought to be definitely abandoned.

39. It is however evident that, on the completion of the diversions, actual and proposed, by the upper Riparian States, the channel from the lowest lock, near Swan Reach to the *debouchement* at Lake Alexandrina, a distance of 114 miles, and thence to the sea mouth, will be exposed, in seasons of low river, to become salt by the influx of water from the sea. In fact from Swan Reach downward the river channel will gradually become normally salt. The principal interests affected by this change would be:—228 miles of river frontage, with the lands to a distance of, say, six miles from the river banks; the South Australian railways, in respect of the water services at Murray Bridge and at Tailem Bend; the towns of Mannum, Murray Bridge, Tailem Bend, and Wellington, and some minor hamlets, in respect of their domestic and general water supplies; and about 7,000 acres of reclaimed river flats, protected by flood embankments and occupied by settlers; with a further 29,000 acres of similar lands that might be reclaimed and settled. The most obvious means of excluding the sea from this portion of the channel, and maintaining fresh water therein, would be the construction of a barrage at the *debouchement*, between the capes—locally known as Pomanda Point and Low Point—on either side the entrance to the arm of Lake Alexandrina into which the river waters are discharged; with a by-pass, and lock, across the neck of the peninsula that forms the boundary of the arm on the west; and the maintenance of a constant stream of fresh water from above, to

to make good the loss by evaporation in this limited area. The barrage would be three miles in length, that being the distance between the capes; and the level of its crest one foot above gravity surface of water in lakes. The maximum volume of river flood, to be discharged over the crest, must be assumed as 6,000,000 cub. ft. per minute. Adopting a reasonable velocity of 3ft. per second, 2·045 miles per hour, the depth of water on the crest of the barrage, during the discharge of such floods, would be 2·10ft. The pass would be an excavated channel of 50ft. bed width, by 7ft. carrying depth, and about 2,000ft. in length; from the fresh water impounded in the arm to the salt water in Lake Alexandrina; with a lock at a suitable site to admit of the passage of boats, while preventing the flux or reflux of water between them. The highest level of surface of flood water, in front of the barrage, above normal level of Lake Alexandrina, would thus be 3·10ft.; the ordinary drop for boats passing through the lock, from the fresh water of the river to salt water in the lake, 1ft.; and the maximum drop during extreme river floods, 3 10ft. It is impossible here to give anything like a detailed design of the works involved in this proposal, or any reliable estimate of their cost. This could not be undertaken without an expenditure of time and money not warranted by the instructions under which this report has been prepared. As an approximation, a barrage of rough stone, with internal re-inforcement, the body of the most suitable material procurable in the vicinity, the exposed faces of random granite blocks from the quarries near Mannum; top width 10ft., external slopes 1 to 1, may be expected to cost not less than £135,000. The pass, of the dimensions given, with a lock of cement concrete masonry, of like dimensions with those in the river, may be expected, should the ground prove favorable, to cost £20,000 or £25,000. For the entire work, say, £160,000. Besides the cost of the barrage, pass, and lock, there has to be considered the protective levées of the 7,000 acres of lands mentioned above as reclaimed and settled; and the enhancement of cost of reclaiming the 29,000 acres of reclaimable flats, that certainly will be reclaimed and settled, if the lower river be not caused to become salt. The alternative to the construction of the barrage, or of some effective work to exclude sea water from the lower river, is supply by pumping from above Swan Reach, if the river be canalised; from some indefinite point above Morgan, if it be not canalised; and the conveyance of the pumped water—by channels or otherwise—to the railway stations at Murray Bridge and Tailem Bend; to the towns and hamlets on the river banks; and to the lands near the river requiring a supply. There is also to be taken into account the fact that 7,000 acres of land, reclaimed and occupied, will have to be abandoned; and that 29,000 acres of valuable reclaimable land will be rendered irreclaimable.

40. The foregoing statement as to the inevitable saltness of the lower Murray, in the event of the diversion of the upper waters, without due provision for a compensation supply, may appear startling. Of the facts, however, there seems no room for doubt; a comparison of the tide gauge levels with those in the lakes and lower river, puts them beyond question. Taking as datum the level of ordinary low water springs, in the open sea, outside the entrance, and adopting it as zero, we have, from the recorded tide gaugings, the following levels, invariable, save to a very limited extent under the influence of continued high winds:—

| | |
|---|---|
| At Goolwa | 0·80 |
| " Milang | 0·52 |
| " Meningie, at head of Lake Albert | 1·11 |

That they are not absolutely identical need occasion no surprise; the differences may be due to imperfections of observation, or to the influence of the form of coast-line, or in part to each of these causes. The high level at Meningie may, with reason, be ascribed to the obstruction caused by the narrowness of the entrance to Lake Albert. But, at Morgan, 158 miles above the site of the proposed barrage between Pomanda Point and Low Point, the level of the surface of water in the river, throughout April, May, and June, in 1902, and March and April, 1903, at the culmination of the long drought, was 0·87 above zero; that is to say it was, to all intents and purposes, identical with that of the surface of water in the lakes. During those months the volume flowing in the Murray at Morgan remained steadily at 24,000 cub. ft. per minute, the equivalent of 13,000 millions of cubic feet per annum. The state of the river at Morgan, should diversions be increased to such an extent as to reduce the volume there to 24,000 cub. ft. per minute, will inevitably be that of an ordinary arm of the sea, slightly modified by the access of a small fresh water creek.

41. The reclamation of the lake beds, and their conversion into habitable land, another proposal that has to be considered, would, within certain limits, effect the same purpose as that aimed at by the construction of the barrage referred to in 38. It would diminish the loss by evaporation, by reducing the area of surface exposed to the action of sun and wind; so that, in time, the surplus discharge of the river, even in low years, might be sufficient to maintain fresh water throughout the reduced area. It would certainly be many years before the reduction of water surface could be expected to reach such proportions as to establish a constant balance between the loss by evaporation and the gain by the river surplus. Still, that condition is the point that would be ultimately attained, and towards which progress would constantly move. Such a proposal as the reclamation of these lakes is by no means without precedent. A large part of the County of Lincoln, in England, known as the fen country, has been reclaimed from the sea; and for centuries kept dry, habitable, and culturable, by unremitting pumping. The same is true of almost the entire area of the Kingdom of Holland. There need be no question as to the possibility of the thing being done; the doubt is, whether the game is worth the candle. Neither need there be any serious question as to the value of the reclaimed land, for pastoral and agricultural settlement. It would, for a time, no doubt, prove infertile by excess of salt in the soil; but that condition would gradually disappear, as the salt got washed into the drains and sump wells, and removed by the pumps. The minor project, at present under discussion, is the reclamation of Lake Albert. Some idea of the character and surroundings of this lake may be gathered from the following notes of a personal inspection:—

Lake Albert; 15th October, 1909.—The entrance to the lake, from the jetty on one side to the lighthouse on the other, is about 1,700ft. wide. The depth in the navigation channel, where it crosses the line of the proposed reclamation embankment, as shown on the plans, is from 7ft. to 8ft. Further up, in the narrows, it shoals to about 3ft. 6in.; the channel being flanked by reedbeds and swamps. Further up still, about two and a half miles above the jetty, the depth was about 7ft. Following the usual navigation track, up the lake, towards Meningie, further soundings gave 6ft., 8ft., and 7ft. 6in. The bulk of the land, in private hands, around Lake Albert, as well as the bulk of lands so held around the lakes in general, whether freehold or leasehold, is occupied for pastoral rather than for agricultural purposes. The area of cultivation

cultivation is very small, even where the soil is (apparently) of good quality, and of character adapted for tillage. At present the water of the lake is fresh, or nearly so: but, especially in the upper part of the lake, it has a disagreeable flavor, like that from a swamp or stagnant pool. The settlers on the lands bordering the lake are supplied by surface water, collected in small dams, or water paddocks. Water for culinary and other domestic purposes is collected from the roofs and stored in tanks. The township of Meningie, about 120 inhabitants, is thus supplied.

42. A special danger to which persons residing near the areas undergoing reclamation will be exposed is liability to malarial fever. This will be understood from the following extract from a report to the Foreign Office, by the British Consular Agent in the Netherlands, on the *Draining of the Zuider Zee*:—"With respect to the results of the reclamation from a hygienic point of view the following remarks may be made on the basis of the observations of the States Commission on the subject:—During the process of reclaiming, the drying marshy soil may bring about the development of malarial diseases. The same will be the case in the first few years after the reclamation, during the subdivision and preparation of the ground. The workmen employed in these occupations will be exposed to malarial influences. The manner in which the work will be carried on will, however, greatly influence the hygienic conditions under which the workmen are placed. By arranging the reclamation in successive and not too large areas, and shortening as much as possible the marshy stage; furthermore, by making the water-level sink as quickly as possible, and so far as is practicable by keeping it at an equal height, we have it in our power to shorten the malaria period. Besides we are now better equipped against malaria, both preventively and curatively, than formerly. The probability that malarial sickness would spread to any considerable distance from the place of its origin is very slight. The possibility of being attacked by malaria will remain confined to the reclaimed polders themselves, or the near neighborhood, along the shore of the Zuider Zee. When once, however, the dangerous period is passed, the condition of the coast lands may be considered as most probably more favorable to health than it is now." But, these reclamations once begun, and a certain measure of success attained, the work is sure to progress. The value of the reclaimed lands will determine public opinion in its favor. And, as it progresses, many improvements in the mode of its execution, in the alignment and location of the drainage channels, and in the slope and dressing of the surface soil, will suggest themselves. Eventually, the channel of the Murray River will probably be carried down to the sea, following a course, from the present mouth, about six miles below Wellington, so as to leave Point McLeay on the left and Point Sturt on the right; thus converting the bed of Lake Alexandrina, excepting only the channel itself, into dry land. From Point McLeay, the levée forming the left bank of the channel would make direct for the eastern point of Long Island; while Long Island would be connected to Mundoo Island, and thence to the Younghusband Peninsula, by continuing the levée across the channels. The river water would then find its sole exit by the existing sea mouth; or by some other mouth opened in substitution therefor, through the sandhills. But the completion of such an undertaking belongs to a time so far in the future that the discussion of its details partakes rather of the nature of vague speculation than of tangible reality. Some idea of its probable cost may be gained from a brief statement of the pumping work alone to be performed, in the drying of Lake Albert. The removal of the volume of water lying on the lake bed, and of that contained in the soil underlying the bed, to a depth of about 3ft. or 3½ft., and its discharge into the new channel near Point McLeay, would absorb the entire work of a pumping plant of 600 effective horsepower, during 340—24-hour days; in round numbers, one year of the plant running three shifts continuously.

Assistance in the preparation of this report has been rendered by Mr. J. W. Jones, Secretary to the Commissioner for Public Works, and by Mr. Graham Stewart, Engineer-in-Chief; by the supply of statements of fact and documents for reference; as well as by valuable suggestions and friendly criticism during the passage of the matter through the press.

Besides the several reports and documents mentioned in the foregoing, the following have been consulted:—

Proposed River Murray Canal, H. C. Mais (2)—8-7-74 and 9-7-74.
Port Victor Harbor Works, W. B. Hull—6-7-75.
Victor Harbor and Murray Mouth, Hickson and Goalen—27-7-76.
Navigability of Murray Mouth, R. Hickson—12-9-76.
Victor Harbor Breakwater, Marine Board—13-10-82.
Construction of Locks near Murray Mouth, A. B. Moncrieff—25-9-90.

Adelaide, Feb., 1910. STUART MURRAY.

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The following is a summary of the principal figures, expressive of volumes of water, given in the body of the report:—

Volume required to provide for navigation, the Murray being in its present condition as an open river—

| | Cub. Ft. Per Min. |
|---|---|
| At Mildura— | |
| For boats of 5ft. draught, with 18in. clearance | 274,000 |
| " 3ft. 6in. " 6in. " | 125,499 |
| At the eastern boundary of South Australia— | |
| For boats of 5ft. draught, with 18in. clearance | 428,950 |
| " 3ft. 6in. " 6in. " | 313,870 |
| At Morgan, corresponding to the volumes at the boundary— | |
| For boats of 5ft, draught, with 18in. clearance | 390,000 |
| " 3ft. 6in. " 6in. " | 227,000 |

Volume

Volume required to provide for evaporation, soakage, and lockage, on the Murray as a canalised river.

| | Cub. Ft. Per Min. |
|---|---|
| At the eastern boundary of South Australia | 30,000 |

Actual loss of water entailed by navigation on the Murray as a canalised river—

| | Cub. Ft. Per Annum. |
|---|---|
| In the State of South Australia | 8,000,000,000 |
| Throughout the entire system, on the Murray and Murrumbidgee | 18,500,000,000 |

| | |
|---|---|
| Volume required for domestic, stock, and general supply, for land in dry farming areas, 1,500,000 acres, at 750 gals., equal to 120 cub. ft. per acre, per annum | 180,000,000 |
| At eastern boundary, for continuous navigation (the equivalent of 30,000 cub. ft. per minute) | 15,750,000,000 |
| For irrigation of one-fourth of the total area irrigable, as given in Mr. Jones's evidence, $\frac{2,500,000}{4}$ acres, irrigated to a depth of 2ft., with an allowance of $\frac{1}{3}$ of that actually used, for waste; the area at present irrigated, or in process of being brought under irrigation, being 15,000 acres | 72,600,000,000 |
| Total, in cub. ft. per annum | 88,530,000,000 |

Adelaide, February, 1910.

S. M.

TABLE

## TABLE I.—GAUGINGS OF THE MURRAY RIVER AT MILDURA,

*The navigable channel bed being taken as 2ft. 9in. below zero of gauge.*

| Month. | Mean Volume—Cub. Ft. per Min. | Monthly Totals—Millions of Cub. Ft. | Mean Depth on Nav. Chl. Bed. |
|---|---|---|---|
| **1886** | | | Ft. In. |
| January | 304,700 | 13,602 | 6 11 |
| February | 226,500 | 9,132 | 5 10 |
| March | 221,900 | 9,906 | 5 9 |
| April | 139,300 | 6,018 | 4 4 |
| May | 111,300 | 4,968 | 3 8 |
| June | 190,000 | 8,208 | 5 3 |
| July | 217,300 | 9,700 | 5 8 |
| August | 338,000 | 15,088 | 7 4 |
| September | 723,200 | 31,242 | 12 11 |
| October | 986,000 | 44,015 | 15 9 |
| November | 1,003,500 | 43,351 | 15 11 |
| December | 935,500 | 41,761 | 15 3 |
| Total for year | | 236,991 | |
| **1887** | | | Ft. In. |
| January | 702,400 | 31,355 | 12 8 |
| February | 314,700 | 12,689 | 7 1 |
| March | 366,000 | 16,338 | 7 9 |
| April | 484,000 | 20,909 | 9 9 |
| May | 564,900 | 25,217 | 10 11 |
| June | 444,000 | 19,181 | 9 1 |
| July | 751,500 | 33,547 | 13 3 |
| August | 1,355,800 | 60,523 | 19 2 |
| September | 1,967,960 | 85,018 | 24 1 |
| October | 1,952,270 | 87,151 | 24 0 |
| November | 1,924,530 | 83,138 | 23 10 |
| December | 1,887,450 | 84,254 | 23 6 |
| Total for year | | 559,320 | |
| **1888** | | | Ft. In. |
| January | 1,679,120 | 74,955 | 22 0 |
| February | 780,510 | 32,594 | 13 7 |
| March | 335,500 | 14,977 | 7 4 |
| April | 243,870 | 10,536 | 6 1 |
| May | 217,970 | 9,732 | 5 9 |
| June | 294,240 | 12,709 | 6 9 |
| July | 570,410 | 25,463 | 11 0 |
| August | 783,570 | 34,980 | 13 8 |
| September | 836,460 | 36,137 | 14 3 |
| October | 925,710 | 41,323 | 15 2 |
| November | 858,930 | 37,104 | 14 6 |
| December | 532,090 | 23,753 | 10 5 |
| Total for year | | 354,263 | |
| **1889** | | | Ft. In. |
| January | 399,570 | 17,838 | 8 4 |
| February | 501,170 | 20,208 | 10 0 |
| March | 244,810 | 10,928 | 6 1 |
| April | 113,870 | 4,921 | 3 9 |
| May | 278,480 | 12,432 | 6 7 |
| June | 795,120 | 34,348 | 13 9 |
| July | 1,416,430 | 63,228 | 19 9 |
| August | 2,312,710 | 103,240 | 25 11 |
| September | 1,809,450 | 78,176 | 23 0 |
| October | 2,719,890 | 121,416 | 27 8 |
| November | 2,391,940 | 103,330 | 26 3 |
| December | 1,622,590 | 72,433 | 21 6 |
| Total for year | | 642,498 | |

| Month. | Mean Volume—Cub. Ft. per Min. | Monthly Totals—Millions of Cub. Ft. | Mean Depth on Nav. Chl. Bed. |
|---|---|---|---|
| **1890** | | | Ft. In. |
| January | 800,560 | 35,739 | 13 10 |
| February | 276,780 | 11,161 | 6 6 |
| March | 255,900 | 11,423 | 6 3 |
| April | 327,380 | 14,144 | 7 3 |
| May | 276,970 | 12,365 | 6 6 |
| June | 449,970 | 19,440 | 9 2 |
| July | 1,025,310 | 45,769 | 16 1 |
| August | 1,553,490 | 69,358 | 20 11 |
| September | 1,766,110 | 76,296 | 22 8 |
| October | 1,770,920 | 79,053 | 22 9 |
| November | 1,634,230 | 70,597 | 21 7 |
| December | 1,593,150 | 71,116 | 21 3 |
| Total for year | | 516,461 | |
| **1891** | | | Ft. In. |
| January | 1,137,950 | 50,796 | 17 2 |
| February | 850,040 | 34,272 | 14 4 |
| March | 641,240 | 28,558 | 11 11 |
| April | 436,850 | 18,870 | 9 0 |
| May | 474,590 | 21,196 | 9 7 |
| June | 439,630 | 18,991 | 9 0 |
| July | 717,350 | 32,020 | 12 10 |
| August | 1,897,640 | 84,709 | 23 7 |
| September | 2,285,040 | 98,712 | 25 10 |
| October | 1,428,390 | 63,764 | 19 10 |
| November | 1,103,330 | 47,633 | 16 10 |
| December | 772,750 | 34,493 | 13 6 |
| Total for year | | 534,014 | |
| **1892** | | | Ft. In. |
| January | 491,860 | 21,958 | 9 10 |
| February | 273,590 | 11,425 | 6 6 |
| March | 164,770 | 7,357 | 4 10 |
| April | 80,190 | 3,465 | 2 11 |
| May | 190,200 | 8,491 | 5 3 |
| June | 429,990 | 18,576 | 8 10 |
| July | 675,240 | 30,141 | 12 4 |
| August | 931,720 | 41,591 | 15 3 |
| September | 954,370 | 41,230 | 15 5 |
| October | 1,268,750 | 56,635 | 18 4 |
| November | 1,383,000 | 59,746 | 19 5 |
| December | 1,318,580 | 58,862 | 18 10 |
| Total for year | | 359,477 | |
| **1893** | | | Ft. In. |
| January | 840,650 | 37,524 | 14 3 |
| February | 297,300 | 11,987 | 6 10 |
| March | 214,800 | 9,589 | 5 8 |
| April | 203,770 | 8,804 | 5 6 |
| May | 247,870 | 11,066 | 6 2 |
| June | 481,830 | 20,814 | 9 9 |
| July | 1,006,210 | 44,917 | 15 11 |
| August | 1,449,390 | 64,701 | 20 0 |
| September | 1,797,110 | 77,635 | 22 11 |
| October | 1,593,730 | 71,143 | 21 3 |
| November | 1,839,000 | 79,445 | 23 2 |
| December | 1,648,780 | 73,602 | 21 9 |
| Total for year | | 511,227 | |

MILDURA GAUGINGS—*continued.*

| Month. | Mean Volume—Cub. Ft. per Min. | Monthly Totals—Millions of Cub. Ft. | Mean Depth on Nav. Chl. Bed. Ft. | In. |
|---|---|---|---|---|
| **1894** | | | | |
| January | 702,500 | 31,360 | 12 | 8 |
| February | 514,950 | 20,761 | 10 | 2 |
| March | 342,300 | 15,280 | 7 | 5 |
| April | 413,960 | 17,885 | 8 | 7 |
| May | 605,200 | 27,016 | 11 | 5 |
| June | 829,160 | 35,822 | 14 | 2 |
| July | 1,171,750 | 52,305 | 17 | 6 |
| August | 1,771,190 | 79,066 | 22 | 9 |
| September | 2,772,910 | 119,789 | 27 | 10 |
| October | 2,887,700 | 128,907 | 28 | 3 |
| November | 2,724,350 | 117,689 | 27 | 8 |
| December | 2,335,160 | 104,243 | 26 | 0 |
| Total for year | | 750,123 | | |
| **1895** | | | | |
| January | 1,168,300 | 52,153 | 17 | 6 |
| February | 469,790 | 18,942 | 9 | 6 |
| March | 347,620 | 15,517 | 7 | 6 |
| April | 275,600 | 11,906 | 6 | 6 |
| May | 287,550 | 12,834 | 6 | 8 |
| June | 379,010 | 16,373 | 8 | 0 |
| July | 620,560 | 27,704 | 11 | 8 |
| August | 789,430 | 35,239 | 13 | 8 |
| September | 863,960 | 37,325 | 14 | 6 |
| October | 1,213,280 | 54,162 | 17 | 10 |
| November | 1,124,980 | 48,600 | 17 | 1 |
| December | 354,590 | 15,829 | 7 | 7 |
| Total for year | | 346,584 | | |
| **1896** | | | | |
| January | 204,230 | 9,115 | 5 | 6 |
| February | 114,620 | 4,786 | 3 | 9 |
| March | 117,450 | 5,241 | 3 | 10 |
| April | 121,900 | 5,266 | 3 | 11 |
| May | 323,620 | 14,446 | 7 | 2 |
| June | 403,510 | 17,431 | 8 | 5 |
| July | 533,810 | 23,829 | 10 | 6 |
| August | 699,460 | 31,226 | 12 | 8 |
| September | 550,560 | 23,786 | 10 | 9 |
| October | 733,510 | 32,743 | 13 | 0 |
| November | 540,880 | 23,367 | 10 | 7 |
| December | 318,510 | 14,218 | 7 | 1 |
| Total for year | | 205,454 | | |
| **1897** | | | | |
| January | 187,100 | 8,352 | 5 | 2 |
| February | 334,870 | 13,503 | 7 | 4 |
| March | 174,520 | 7,790 | 5 | 0 |
| April | 123,030 | 5,314 | 3 | 11 |
| May | 78,440 | 3,500 | 2 | 11 |
| June | 82,100 | 3,547 | 3 | 0 |
| July | 258,140 | 11,522 | 6 | 3 |
| August | 467,990 | 20,892 | 9 | 6 |
| September | 697,930 | 30,149 | 12 | 7 |
| October | 960,520 | 42,877 | 15 | 6 |
| November | 817,590 | 35,320 | 14 | 0 |
| December | 325,230 | 14,517 | 7 | 2 |
| Total for year | | 197,283 | | |
| **1898** | | | | |
| January | 104,350 | 4,656 | 3 | 6 |
| February | 50,980 | 2,056 | 2 | 0 |
| March | 119,060 | 5,317 | 3 | 10 |
| April | 57,410 | 2,480 | 2 | 3 |
| May | 58,420 | 2,607 | 2 | 3 |
| June | 144,060 | 6,225 | 4 | 5 |
| July | 517,440 | 23,097 | 10 | 3 |
| August | 554,320 | 24,744 | 10 | 9 |
| September | 824,460 | 35,618 | 14 | 1 |
| October | 905,600 | 40,426 | 14 | 11 |
| November | 691,480 | 29,873 | 12 | 6 |
| December | 608,390 | 27,159 | 11 | 6 |
| Total for year | | 204,258 | | |
| **1899** | | | | |
| January | 231,470 | 10,334 | 5 | 11 |
| February | 112,710 | 4,544 | 3 | 9 |
| March | 60,340 | 2,693 | 2 | 4 |
| April | 100,010 | 4,320 | 3 | 5 |
| May | 200,190 | 8,937 | 5 | 5 |
| June | 286,490 | 12,377 | 6 | 8 |
| July | 695,110 | 31,029 | 12 | 7 |
| August | 956,970 | 42,720 | 15 | 6 |
| September | 837,890 | 36,197 | 14 | 3 |
| October | 506,770 | 22,624 | 10 | 1 |
| November | 460,930 | 19,911 | 9 | 4 |
| December | 313,650 | 13,999 | 7 | 1 |
| Total for year | | 209,685 | | |
| **1900** | | | | |
| January | 67,500 | 3,013 | 2 | 7 |
| February | 51,890 | 2,093 | 2 | 1 |
| March | 36,870 | 1,647 | 1 | 5 |
| April | 141,870 | 6,130 | 4 | 4 |
| May | 400,570 | 17,883 | 8 | 4 |
| June | 516,250 | 22,300 | 10 | 3 |
| July | 749,630 | 33,462 | 13 | 3 |
| August | 1,275,130 | 56,920 | 18 | 5 |
| September | 1,269,340 | 54,834 | 18 | 5 |
| October | 1,532,670 | 68,420 | 20 | 9 |
| November | 1,405,210 | 60,705 | 19 | 7 |
| December | 602,470 | 26,896 | 11 | 5 |
| Total for year | | 354,303 | | |
| **1901** | | | | |
| January | 172,320 | 7,691 | 4 | 11 |
| February | 84,020 | 3,387 | 3 | 0 |
| March | 40,940 | 1,826 | 1 | 8 |
| April | 39,940 | 1,724 | 1 | 7 |
| May | 140,670 | 6,281 | 4 | 4 |
| June | 175,600 | 7,586 | 5 | 0 |
| July | 438,290 | 19,566 | 9 | 0 |
| August | 405,740 | 18,110 | 8 | 5 |
| September | 553,670 | 23,920 | 10 | 9 |
| October | 856,100 | 38,216 | 14 | 5 |
| November | 999,230 | 43,165 | 15 | 11 |
| December | 871,870 | 38,922 | 14 | 7 |
| Total for year | | 210,394 | | |

MILDURA GAUGINGS—*continued.*

| Month. | Mean Volume—Cub. Ft. per Min. | Monthly Totals—Millions of Cub. Ft. | Mean Depth on Nav. Chl. Bed. |
|---|---|---|---|
| **1902** | | | Ft. In. |
| January | 213,870 | 9,548 | 5 8 |
| February | 92,860 | 3,746 | 3 3 |
| March | 36,060 | 1,612 | 1 5 |
| April | 52,630 | 2,272 | 2 1 |
| May | 43,530 | 1,942 | 1 9 |
| June | 40,600 | 1,754 | 1 8 |
| July | 193,470 | 8,638 | 5 4 |
| August | 166,420 | 7,428 | 4 10 |
| September | 94,630 | 4,087 | 3 3 |
| October | 154,000 | 6,875 | 4 7 |
| November | 140,500 | 6,070 | 4 4 |
| December | 50,890 | 2,272 | 2 0 |
| Total for year | | 56,244 | |
| **1903** | | | Ft. In. |
| January | 87,160 | 3,893 | 3 1 |
| February | 33,120 | 1,335 | 1 3 |
| March | 17,880 | 799 | 0 3 |
| April | 22,700 | 981 | 0 8 |
| May | 163,150 | 7,281 | 4 10 |
| June | 231,700 | 10,009 | 5 11 |
| July | 533,710 | 23,824 | 10 6 |
| August | 793,160 | 35,408 | 13 9 |
| September | 690,800 | 29,843 | 12 6 |
| October | 860,740 | 38,422 | 14 6 |
| November | 907,100 | 39,187 | 15 0 |
| December | 538,130 | 24,021 | 10 7 |
| Total for year | | 215,003 | |
| **1904** | | | Ft. In. |
| January | 350,840 | 15,660 | 7 7 |
| February | 373,070 | 15,581 | 7 10 |
| March | 149,350 | 6,665 | 4 6 |
| April | 70,930 | 3,063 | 2 9 |
| May | 59,030 | 2,634 | 2 4 |
| June | 131,130 | 5,664 | 4 1 |
| July | 397,740 | 17,753 | 8 4 |
| August | 791,320 | 35,324 | 13 9 |
| September | 945,970 | 40,867 | 15 4 |
| October | 1,025,390 | 45,774 | 16 2 |
| November | 960,470 | 41,494 | 15 6 |
| December | 878,160 | 39,203 | 14 8 |
| Total for year | | 269,682 | |
| **1905** | | | Ft. In. |
| January | 251,550 | 11,231 | 6 2 |
| February | 79,150 | 3,189 | 2 11 |
| March | 42,090 | 1,879 | 1 9 |
| April | 36,210 | 1,564 | 1 5 |
| May | 64,960 | 2,902 | 2 6 |
| June | 130,870 | 5,655 | 4 1 |
| July | 517,130 | 23,083 | 10 3 |
| August | 1,022,230 | 45,631 | 16 1 |
| September | 1,455,800 | 62,891 | 20 1 |
| October | 1,053,100 | 47,010 | 16 5 |
| November | 966,670 | 41,761 | 15 7 |
| December | 903,190 | 40,319 | 14 11 |
| Total for year | | 287,115 | |
| **1906** | | | Ft. In. |
| January | 368,350 | 16,441 | 7 9 |
| February | 104,970 | 4,234 | 3 6 |
| March | 74,830 | 3,339 | 2 10 |
| April | 233,900 | 10,104 | 5 1 |
| May | 291,710 | 13,021 | 6 9 |
| June | 593,200 | 25,626 | 11 3 |
| July | 875,100 | 38,261 | 14 5 |
| August | 1,466,710 | 65,473 | 20 2 |
| September | 1,914,900 | 82,724 | 23 9 |
| October | 2,315,260 | 103,355 | 25 11 |
| November | 2,682,500 | 115,984 | 27 6 |
| December | 1,836,480 | 81,981 | 23 2 |
| Total for year | | 560,543 | |
| **1907** | | | Ft. In |
| January | 927,480 | 41,404 | 15 2 |
| February | 359,640 | 14,499 | 7 8 |
| March | 187,550 | 8,374 | 5 3 |
| April | 133,800 | 5,780 | 4 2 |
| May | 182,230 | 8,133 | 5 1 |
| June | 273,070 | 11,798 | 6 6 |
| July | 350,000 | 15,624 | 7 6 |
| August | 511,900 | 22,851 | 10 2 |
| September | 748,400 | 32,331 | 13 3 |
| October | 637,740 | 28,467 | 11 10 |
| November | 508,870 | 21,984 | 10 1 |
| December | 390,520 | 17,432 | 8 2 |
| Total for year | | 228,677 | |
| **1908** | | | Ft. In. |
| January | 266,350 | 11,888 | 6 5 |
| February | 104,590 | 4,368 | 3 6 |
| March | 71,710 | 3,201 | 2 9 |
| April | 50,040 | 2,160 | 2 0 |
| May | 58,620 | 2,616 | 2 4 |
| June | 141,730 | 6,121 | 4 4 |
| July | 389,193 | 17,374 | 8 2 |
| August | 509,387 | 22,740 | 10 1 |
| September | 602,266 | 26,019 | 11 5 |
| October | 778,290 | 34,743 | 13 7 |
| November | 703,366 | 30,387 | 12 8 |
| December | 373,419 | 16,669 | 7 11 |
| Total for year | | 178,286 | |

TABLE II.—COMPUTED VOLUMES OF THE MURRAY RIVER AT THE EASTERN BOUNDARY OF SOUTH AUSTRALIA.

*The Navigable Channel Bed being taken as 2ft. 1in. below the water surface corresponding to zero on the Renmark Gauge.*

| Month. | Mean Volume—Cub. Ft. per Min. | Monthly Totals—Millions of Cub. Ft. | Mean Depth on Nav. Chl. Bed. Ft. | In. |
|---|---|---|---|---|
| **1886** | | | | |
| January | 416,000 | 18,539 | 6 | 4 |
| February | 328,000 | 13,200 | 4 | 4 |
| March | 298,000 | 13,281 | 3 | 8 |
| April | 241,000 | 10,417 | 2 | 4 |
| May | 161,000 | 7,168 | 0 | 10 |
| June | 136,000 | 5,903 | 0 | 4 |
| July | 241,000 | 10,758 | 2 | 4 |
| August | 539,000 | 24,063 | 7 | 9 |
| September | 955,000 | 41,254 | 11 | 7 |
| October | 1,342,000 | 59,954 | 14 | 5 |
| November | 1,562,000 | 67,530 | 15 | 8 |
| December | 1,716,000 | 76,696 | 16 | 6 |
| Total for year | | 348,763 | | |
| **1887** | | | | |
| January | 1,481,000 | 66,349 | 15 | 2 |
| February | 1,071,000 | 43,178 | 12 | 6 |
| March | 951,000 | 42,437 | 11 | 7 |
| April | 910,000 | 39,347 | 11 | 3 |
| May | 1,095,000 | 48,892 | 12 | 8 |
| June | 1,117,000 | 48,223 | 12 | 10 |
| July | 1,139,000 | 50,827 | 13 | 0 |
| August | 1,296,000 | 57,804 | 14 | 2 |
| September | 1,935,000 | 83,576 | 17 | 9 |
| October | 2,476,000 | 110,529 | 20 | 9 |
| November | 2,445,000 | 105,612 | 20 | 7 |
| December | 2,366,000 | 105,612 | 20 | 1 |
| Total for year | | 802,386 | | |
| **1888** | | | | |
| January | 2,615,000 | 116,731 | 21 | 6 |
| February | 2,302,000 | 96,162 | 19 | 9 |
| March | 945,000 | 42,187 | 11 | 6 |
| April | 724,000 | 31,251 | 9 | 9 |
| May | 673,000 | 30,069 | 9 | 2 |
| June | 446,000 | 19,263 | 6 | 8 |
| July | 531,000 | 23,679 | 7 | 8 |
| August | 831,000 | 37,095 | 10 | 7 |
| September | 1,006,000 | 43,452 | 12 | 0 |
| October | 1,067,000 | 47,621 | 12 | 5 |
| November | 945,000 | 40,822 | 11 | 6 |
| December | 531,000 | 23,679 | 7 | 8 |
| Total for year | | 552,011 | | |
| **1889** | | | | |
| January | 371,000 | 16,557 | 5 | 4 |
| February | 492,000 | 19,800 | 7 | 2 |
| March | 336,000 | 14,965 | 4 | 6 |
| April | 209,000 | 8,983 | 1 | 9 |
| May | 236,000 | 10,533 | 2 | 3 |
| June | 628,000 | 27,069 | 8 | 8 |
| July | 1,161,000 | 51,816 | 13 | 2 |
| August | 2,092,000 | 93,356 | 18 | 7 |
| September | 2,963,000 | 127,998 | 23 | 5 |
| October | 2,743,000 | 122,467 | 22 | 2 |
| November | 3,237,000 | 139,850 | 24 | 11 |
| December | 2,963,000 | 132,265 | 23 | 5 |
| Total for year | | 765,659 | | |

| Month. | Mean Volume—Cub. Ft. per Min. | Monthly Totals—Millions of Cub. Ft. | Mean Depth on Nav. Chl. Bed. Ft. | In. |
|---|---|---|---|---|
| **1890** | | | | |
| January | 1,925,000 | 85,941 | 17 | 8 |
| February | 726,000 | 29,258 | 9 | 9 |
| March | 676,000 | 30,167 | 9 | 3 |
| April | 726,000 | 31,347 | 9 | 9 |
| May | 890,000 | 39,733 | 11 | 1 |
| June | 1,069,000 | 46,169 | 12 | 5 |
| July | 2,740,000 | 122,329 | 22 | 2 |
| August | 3,617,000 | 161,474 | 27 | 1 |
| September | 4,056,000 | 175,207 | 29 | 6 |
| October | 4,056,000 | 181,047 | 29 | 6 |
| November | 3,234,000 | 139,692 | 24 | 11 |
| December | 2,850,000 | 127,222 | 22 | 10 |
| Total for year | | 1,169,586 | | |
| **1891** | | | | |
| January | 2,616,000 | 116,776 | 21 | 6 |
| February | 2,122,000 | 85,543 | 18 | 9 |
| March | 1,708,000 | 76,236 | 16 | 5 |
| April | 1,478,000 | 63,833 | 15 | 2 |
| May | 1,233,000 | 55,060 | 13 | 8 |
| June | 1,198,000 | 51,758 | 13 | 5 |
| July | 1,233,000 | 55,062 | 13 | 8 |
| August | 1,478,000 | 65,961 | 15 | 2 |
| September | 2,740,000 | 118,384 | 22 | 2 |
| October | 2,740,000 | 122,330 | 22 | 2 |
| November | 2,124,000 | 91,771 | 18 | 9 |
| December | 1,478,000 | 65,961 | 15 | 2 |
| Total for year | | 968,675 | | |
| **1892** | | | | |
| January | 1,437,000 | 62,732 | 14 | 11 |
| February | 1,005,000 | 41,986 | 11 | 11 |
| March | 626,000 | 27,929 | 8 | 8 |
| April | 370,000 | 16,000 | 5 | 3 |
| May | 299,000 | 13,354 | 3 | 8 |
| June | 533,000 | 23,004 | 7 | 8 |
| July | 725,000 | 32,381 | 9 | 9 |
| August | 1,234,000 | 55,041 | 13 | 9 |
| September | 1,406,000 | 60,708 | 14 | 9 |
| October | 1,477,000 | 65,936 | 15 | 2 |
| November | 1,786,000 | 77,157 | 16 | 11 |
| December | 1,925,000 | 85,910 | 17 | 8 |
| Total for year | | 562,738 | | |
| **1893** | | | | |
| January | 1,925,000 | 85,925 | 17 | 8 |
| February | 1,363,000 | 54,982 | 14 | 6 |
| March | 626,000 | 27,934 | 8 | 8 |
| April | 675,000 | 29,187 | 9 | 3 |
| May | 726,000 | 32,387 | 9 | 9 |
| June | 947,000 | 40,906 | 11 | 6 |
| July | 1,334,000 | 59,539 | 14 | 4 |
| August | 1,787,000 | 79,743 | 16 | 11 |
| September | 2,304,000 | 99,517 | 19 | 9 |
| October | 2,740,000 | 122,305 | 22 | 2 |
| November | 2,397,000 | 103,565 | 20 | 3 |
| December | 2,492,000 | 111,201 | 20 | 10 |
| Total for year | | 847,191 | | |

COMPUTED VOLUMES AT EAST BOUNDARY—*continued.*

| Month. | Mean Volume—Cub. Ft. per Min. | Monthly Totals—Millions of Cub. Ft. | Mean Depth on Nav. Chl. Bed. |
|---|---|---|---|
| **1894** | | | Ft. In. |
| January | 2,305,000 | 102,890 | 19 9 |
| February | 1,284,000 | 51,776 | 14 1 |
| March | 780,000 | 34,803 | 10 3 |
| April | 625,000 | 27,048 | 8 8 |
| May | 947,000 | 42,292 | 11 6 |
| June | 1,334,000 | 57,649 | 14 4 |
| July | 1,629,000 | 72,738 | 16 0 |
| August | 1,925,000 | 85,972 | 17 8 |
| September | 2,741,000 | 118,425 | 22 2 |
| October | 3,427,000 | 152,965 | 26 0 |
| November | 3,619,000 | 156,321 | 27 1 |
| December | 3,235,000 | 144,399 | 24 11 |
| Total for year | | 1,047,278 | |
| **1895** | | | Ft. In. |
| January | 2,952,000 | 132,060 | 23 4 |
| February | 1,477,000 | 59,551 | 15 2 |
| March | 675,000 | 30,154 | 9 3 |
| April | 626,000 | 27,027 | 8 8 |
| May | 448,000 | 20,005 | 6 9 |
| June | 370,000 | 15,999 | 5 4 |
| July | 605,000 | 27,027 | 8 5 |
| August | 833,000 | 37,172 | 10 8 |
| September | 1,068,000 | 46,150 | 12 5 |
| October | 1,068,000 | 47,688 | 12 5 |
| November | 1,198,000 | 51,736 | 13 5 |
| December | 1,068,000 | 47,688 | 12 5 |
| Total for year | | 542,257 | |
| **1896** | | | Ft. In. |
| January | 510,000 | 22,750 | 7 5 |
| February | 387,000 | 16,146 | 5 8 |
| March | 408,000 | 18,187 | 6 1 |
| April | 495,000 | 21,394 | 7 3 |
| May | 545,000 | 24,399 | 7 9 |
| June | 577,000 | 24,958 | 8 2 |
| July | 593,000 | 26,458 | 8 4 |
| August | 769,000 | 34,332 | 10 2 |
| September | 913,000 | 39,463 | 11 3 |
| October | 839,000 | 37,417 | 10 8 |
| November | 896,000 | 38,703 | 11 1 |
| December | 575,000 | 25,672 | 8 1 |
| Total for year | | 330,079 | |
| **1897** | | | Ft. In. |
| January | 407,000 | 18,168 | 6 1 |
| February | 457,000 | 18,400 | 6 10 |
| March | 419,000 | 18,691 | 6 4 |
| April | 287,000 | 12,373 | 3 5 |
| May | 233,000 | 10,422 | 2 2 |
| June | 172,000 | 7,439 | 1 0 |
| July | 247,000 | 10,990 | 2 6 |
| August | 517,000 | 23,041 | 7 6 |
| September | 872,000 | 37,682 | 10 11 |
| October | 1,169,000 | 52,164 | 13 3 |
| November | 1,279,000 | 55,214 | 14 1 |
| December | 979,000 | 43,730 | 11 9 |
| Total for year | | 308,314 | |

| Month. | Mean Volume—Cub. Ft. per Min. | Monthly Totals—Millions of Cub. Ft. | Mean Depth on Nav. Chl. Bed. |
|---|---|---|---|
| **1898** | | | Ft. In. |
| January | 343,000 | 15,335 | 4 8 |
| February | 322,000 | 12,967 | 4 2 |
| March | 420,000 | 18,749 | 6 4 |
| April | 493,000 | 21,317 | 7 3 |
| May | 295,000 | 13,195 | 3 7 |
| June | 229,000 | 9,863 | 2 1 |
| July | 499,000 | 22,262 | 7 3 |
| August | 611,000 | 27,292 | 8 6 |
| September | 862,000 | 37,242 | 10 10 |
| October | 1,032,000 | 46,094 | 12 2 |
| November | 1,032,000 | 44,597 | 12 2 |
| December | 879,000 | 39,248 | 11 0 |
| Total for year | | 308,161 | |
| **1899** | | | Ft. In. |
| January | 596,000 | 26,602 | 8 4 |
| February | 222,000 | 8,934 | 2 0 |
| March | 171,000 | 7,643 | 1 0 |
| April | 311,000 | 13,424 | 3 11 |
| May | 314,000 | 14,034 | 4 0 |
| June | 332,000 | 14,379 | 4 5 |
| July | 618,000 | 27,608 | 8 7 |
| August | 995,000 | 44,428 | 11 11 |
| September | 1,102,000 | 47,625 | 12 8 |
| October | 1,062,090 | 47,381 | 12 5 |
| November | 737,000 | 31,857 | 9 11 |
| December | 595,000 | 26,545 | 8 4 |
| Total for year | | 310,460 | |
| **1900** | | | Ft. In. |
| January | 278,000 | 12,430 | 3 2 |
| February | 95,000 | 3,820 | — |
| March | 31,000 | 1,392 | — |
| April | 95,000 | 4,116 | — |
| May | 416,000 | 18,568 | 6 4 |
| June | 564,000 | 24,938 | 8 0 |
| July | 796,000 | 35,552 | 10 4 |
| August | 1,218,000 | 54,418 | 13 7 |
| September | 1,781,000 | 76,988 | 16 10 |
| October | 1,930,000 | 86,141 | 17 8 |
| November | 1,982,000 | 85,600 | 18 0 |
| December | 1,567,000 | 69,014 | 15 8 |
| Total for year | | 472,977 | |
| **1901** | | | Ft. In. |
| January | 523,000 | 23,412 | 7 6 |
| February | 240,000 | 9,657 | 2 4 |
| March | 56,000 | 2,498 | — |
| April | 27,000 | 1,161 | — |
| May | 31,000 | 1,399 | — |
| June | 237,000 | 10,250 | 2 3 |
| July | 417,000 | 18,649 | 6 4 |
| August | 479,000 | 21,419 | 7 1 |
| September | 667,000 | 28,821 | 9 1 |
| October | 985,000 | 43,873 | 11 10 |
| November | 1,270,000 | 55,005 | 14 0 |
| December | 1,233,000 | 55,077 | 13 8 |
| Total for year | | 271,221 | |

COMPUTED VOLUMES AT EAST BOUNDARY—*continued.*

| Month. | Mean Volume—Cub. Ft. per Min. | Monthly Totals—Millions of Cub. Ft. | Mean Depth on Nav. Chl. Bed. |
|---|---|---|---|
| **1902** | | | Ft. In. |
| January | 728,000 | 32,503 | 9 10 |
| February | 288,000 | 12,062 | 3 5 |
| March | 110,000 | 4,905 | — |
| April | 26,000 | 1,141 | — |
| May | 26,000 | 1,178 | — |
| June | 26,000 | 1,156 | — |
| July | 89,000 | 3,981 | — |
| August | 257,000 | 11,498 | 2 9 |
| September | 240,000 | 10,368 | 2 4 |
| October | 167,000 | 7,468 | 0 11 |
| November | 235,000 | 10,150 | 2 3 |
| December | 139,000 | 6,178 | 0 5 |
| Total for year | | 102,588 | |
| **1903** | | | Ft. In. |
| January | 103,000 | 4,626 | — |
| February | 115,000 | 4,649 | — |
| March | 26,000 | 1,156 | — |
| April | 26,000 | 1,141 | — |
| May | 132,000 | 5,892 | 0 3 |
| June | 376,000 | 16,246 | 5 5 |
| July | 592,000 | 26,410 | 8 4 |
| August | 915,000 | 40,851 | 11 3 |
| September | 1,197,000 | 51,698 | 13 5 |
| October | 1,326,000 | 59,247 | 14 4 |
| November | 1,472,090 | 63,556 | 15 2 |
| December | 1,508,000 | 67,320 | 15 4 |
| Total for year | | 342,792 | |
| **1904** | | | Ft. In. |
| January | 1,023,000 | 45,647 | 12 1 |
| February | 927,000 | 38,710 | 11 4 |
| March | 527,000 | 23,523 | 7 7 |
| April | 392,000 | 16,936 | 5 9 |
| May | 357,000 | 15,982 | 5 0 |
| June | 427,000 | 18,421 | 6 6 |
| July | 516,000 | 23,050 | 7 6 |
| August | 872,000 | 38,939 | 10 11 |
| September | 1,175,000 | 50,747 | 13 3 |
| October | 1,375,000 | 61,377 | 14 7 |
| November | 1,310,000 | 56,622 | 14 3 |
| December | 1,271,000 | 56,800 | 14 0 |
| Total for year | | 446,754 | |
| **1905** | | | Ft. In. |
| January | 661,900 | 29,530 | 9 1 |
| February | 256,000 | 10,343 | 2 8 |
| March | 114,000 | 5,104 | — |
| April | 66,000 | 2,879 | — |
| May | 239,000 | 10,644 | 2 4 |
| June | 448,000 | 19,353 | 6 9 |
| July | 609,000 | 27,180 | 8 6 |
| August | 981,000 | 43,799 | 11 9 |
| September | 1,434,000 | 61,959 | 14 11 |
| October | 1,740,000 | 77,686 | 16 8 |
| November | 1,343,000 | 58,031 | 14 5 |
| December | 1,199,000 | 53,542 | 13 5 |
| Total for year | | 400,050 | |

| Month. | Mean Volume—Cub. Ft. per Min. | Monthly Totals—Millions of Cub. Ft. | Mean Depth on Nav. Chl. Bed. |
|---|---|---|---|
| **1906** | | | Ft. In. |
| January | 1,154,000 | 51,518 | 13 1 |
| February | 298,000 | 12,024 | 3 8 |
| March | 249,000 | 11,094 | 2 6 |
| April | 504,000 | 21,740 | 7 4 |
| May | 605,000 | 26,992 | 8 5 |
| June | 714,000 | 30,859 | 9 8 |
| July | 945,000 | 42,185 | 11 6 |
| August | 1,264,000 | 56,430 | 13 11 |
| September | 1,846,000 | 79,727 | 17 3 |
| October | 2,291,000 | 102,258 | 19 8 |
| November | 2,734,000 | 118,117 | 22 2 |
| December | 2,985,000 | 133,265 | 23 7 |
| Total for year | | 686,209 | |
| **1907** | | | Ft. In. |
| January | 2,102,000 | 93,850 | 18 8 |
| February | 1,049,000 | 42,291 | 12 4 |
| March | 705,000 | 31,476 | 9 7 |
| April | 421,000 | 18,200 | 6 5 |
| May | 421,000 | 18,813 | 6 5 |
| June | 415,000 | 17,907 | 6 3 |
| July | 450,000 | 20,064 | 6 9 |
| August | 537,000 | 23,954 | 7 8 |
| September | 822,000 | 35,479 | 10 7 |
| October | 907,000 | 40,494 | 11 2 |
| November | 748,000 | 32,313 | 10 0 |
| December | 575,000 | 25,669 | 8 1 |
| Total for year | | 400,510 | |
| **1908** | | | Ft. In. |
| January | 382,000 | 16,482 | 5 6 |
| February | 302,000 | 12,654 | 3 9 |
| March | 110,000 | 4,910 | — |
| April | 308,000 | 13,327 | 3 10 |
| May | 428,000 | 19,107 | 6 6 |
| June | 467,000 | 20,205 | 6 11 |
| July | 462,000 | 20,625 | 6 10 |
| August | 588,000 | 26,273 | 8 3 |
| September | 739,000 | 31,935 | 9 11 |
| October | 959,000 | 42,816 | 11 7 |
| November | 1,062,000 | 45,893 | 12 5 |
| December | 715,000 | 31,937 | 9 8 |
| Total for year | | 286,164 | |

## TABLE III.—GAUGINGS OF THE MURRAY RIVER AT MORGAN.

*The Navigable Channel Bed being taken as 1ft. 9in. below zero of gauge.*

| Month. | Mean Volume—Cub. Ft. per Min. | Monthly Totals—Millions of Cub. Ft. | Mean Depth on Nav. Chl. Bed. Ft. | In. |
|---|---|---|---|---|
| **1886** | | | | |
| January | 378,000 | 16,856 | 6 | 4 |
| February | 298,000 | 12,001 | 5 | 2 |
| March | 271,000 | 12,075 | 4 | 9 |
| April | 219,000 | 9,471 | 3 | 11 |
| May | 146,000 | 6,517 | 2 | 7 |
| June | 124,000 | 5,367 | 2 | 2 |
| July | 219,000 | 9,781 | 3 | 11 |
| August | 490,000 | 21,878 | 7 | 10 |
| September | 868,100 | 37,508 | 11 | 9 |
| October | 1,220,000 | 54,510 | 14 | 9 |
| November | 1,420,000 | 61,398 | 16 | 3 |
| December | 1,560,000 | 69,732 | 17 | 3 |
| Total for year | | 317,094 | | |
| **1887** | | | | |
| January | 1,350,000 | 60,484 | 15 | 9 |
| February | 976,000 | 39,361 | 12 | 9 |
| March | 867,000 | 38,686 | 11 | 9 |
| April | 830,000 | 35,869 | 11 | 5 |
| May | 998,000 | 44,570 | 12 | 11 |
| June | 1,018,000 | 43,960 | 13 | 1 |
| July | 1,038,000 | 46,334 | 13 | 3 |
| August | 1,181,000 | 52,694 | 14 | 6 |
| September | 1,764,000 | 76,188 | 18 | 8 |
| October | 2,257,000 | 100,758 | 21 | 8 |
| November | 2,229,000 | 96,276 | 21 | 6 |
| December | 2,157,000 | 96,276 | 21 | 1 |
| Total for year | | 731,456 | | |
| **1888** | | | | |
| January | 2,384,000 | 106,428 | 22 | 4 |
| February | 2,099,000 | 87,674 | 20 | 9 |
| March | 862,000 | 38,463 | 11 | 9 |
| April | 660,000 | 28,493 | 9 | 9 |
| May | 614,000 | 27,415 | 9 | 3 |
| June | 407,000 | 17,563 | 6 | 9 |
| July | 484,000 | 21,589 | 7 | 9 |
| August | 758,000 | 33,821 | 10 | 9 |
| September | 917,000 | 39,617 | 12 | 3 |
| October | 973,000 | 43,418 | 12 | 9 |
| November | 862,000 | 37,219 | 11 | 9 |
| December | 484,000 | 21,589 | 7 | 9 |
| Total for year | | 503,289 | | |
| **1889** | | | | |
| January | 338,000 | 15,088 | 5 | 9 |
| February | 447,000 | 18,043 | 7 | 3 |
| March | 306,000 | 13,637 | 5 | 3 |
| April | 190,000 | 8,186 | 3 | 4 |
| May | 215,000 | 9,598 | 3 | 10 |
| June | 572,000 | 24,667 | 8 | 9 |
| July | 1,058,000 | 47,218 | 13 | 5 |
| August | 1,906,000 | 85,072 | 19 | 6 |
| September | 2,700,000 | 116,640 | 23 | 9 |
| October | 2,500,000 | 111,600 | 22 | 9 |
| November | 2,950,000 | 127,440 | 24 | 9 |
| December | 2,700,000 | 120,528 | 23 | 9 |
| Total for year | | 697,717 | | |
| **1890** | | | | |
| January | 1,756,000 | 78,404 | 18 | 7 |
| February | 662,000 | 26,692 | 9 | 9 |
| March | 617,000 | 27,521 | 9 | 3 |
| April | 662,000 | 28,598 | 9 | 9 |
| May | 812,000 | 36,248 | 11 | 3 |
| June | 975,000 | 42,120 | 12 | 9 |
| July | 2,500,000 | 111,600 | 22 | 9 |
| August | 3,300,000 | 147,312 | 25 | 9 |
| September | 3,700,000 | 159,840 | 26 | 9 |
| October | 3,700,000 | 165,168 | 26 | 9 |
| November | 2,950,000 | 127,440 | 24 | 9 |
| December | 2,600,000 | 116,064 | 23 | 3 |
| Total for year | | 1,067,007 | | |
| **1891** | | | | |
| January | 2,387,000 | 106,533 | 22 | 4 |
| February | 1,936,000 | 78,040 | 19 | 9 |
| March | 1,558,000 | 69,549 | 17 | 3 |
| April | 1,348,000 | 58,234 | 15 | 9 |
| May | 1,125,000 | 50,231 | 14 | 0 |
| June | 1,093,000 | 47,218 | 13 | 9 |
| July | 1,125,000 | 50,232 | 14 | 0 |
| August | 1,348,000 | 60,175 | 15 | 9 |
| September | 2,500,000 | 108,000 | 22 | 9 |
| October | 2,500,000 | 111,600 | 22 | 9 |
| November | 1,938,000 | 83,722 | 19 | 9 |
| December | 1,348,000 | 60,175 | 15 | 9 |
| Total for year | | 883,709 | | |
| **1892** | | | | |
| January | 1,282,000 | 57,251 | 15 | 3 |
| February | 917,000 | 38,318 | 12 | 3 |
| March | 571,000 | 25,489 | 8 | 9 |
| April | 338,000 | 14,602 | 5 | 9 |
| May | 273,000 | 12,187 | 4 | 9 |
| June | 486,000 | 20,994 | 7 | 9 |
| July | 662,000 | 29,552 | 9 | 9 |
| August | 1,120,000 | 50,232 | 14 | 0 |
| September | 1,283,000 | 55,404 | 15 | 3 |
| October | 1,348,000 | 60,175 | 15 | 9 |
| November | 1,630,000 | 70,416 | 17 | 9 |
| December | 1,757,000 | 78,404 | 18 | 7 |
| Total for year | | 513,024 | | |
| **1893** | | | | |
| January | 1,757,000 | 78,404 | 18 | 7 |
| February | 1,244,000 | 50,169 | 15 | 0 |
| March | 571,000 | 25,489 | 8 | 9 |
| April | 616,000 | 26,632 | 9 | 3 |
| May | 662,000 | 29,552 | 9 | 9 |
| June | 864,000 | 37,325 | 11 | 9 |
| July | 1,217,000 | 54,327 | 14 | 9 |
| August | 1,631,000 | 72,763 | 17 | 9 |
| September | 2,102,000 | 90,806 | 20 | 9 |
| October | 2,500,000 | 111,600 | 22 | 9 |
| November | 2,187,000 | 94,500 | 21 | 3 |
| December | 2,274,000 | 101,467 | 21 | 9 |
| Total for year | | 773,934 | | |

MORGAN GAUGINGS—*continued.*

| Month. | Mean Volume—Cub. Ft. per Min. | Monthly Totals—Millions of Cub. Ft. | Mean Depth on Nav. Chl. Bed. Ft. In. |
|---|---|---|---|
| **1894** | | | |
| January | 2,102,000 | 93,833 | 20 9 |
| February | 1,171,000 | 47,218 | 14 5 |
| March | 711,000 | 31,739 | 10 3 |
| April | 570,000 | 24,667 | 8 9 |
| May | 864,000 | 38,569 | 11 9 |
| June | 1,217,000 | 52,574 | 14 9 |
| July | 1,486,000 | 66,335 | 16 9 |
| August | 1,756,000 | 78,404 | 18 7 |
| September | 2,500,000 | 108,000 | 22 9 |
| October | 3,125,000 | 139,500 | 25 3 |
| November | 3,300,000 | 142,560 | 25 9 |
| December | 2,950,000 | 131,688 | 24 9 |
| Total for year | | 955,087 | |
| **1895** | | | |
| January | 2,694,000 | 120,528 | 23 9 |
| February | 1,348,000 | 54,351 | 15 9 |
| March | 616,000 | 27,521 | 9 3 |
| April | 571,000 | 24,667 | 8 9 |
| May | 409,000 | 18,258 | 6 9 |
| June | 338,000 | 14,602 | 5 9 |
| July | 552,000 | 24,667 | 8 6 |
| August | 760,000 | 33,926 | 10 9 |
| September | 975,000 | 42,120 | 12 9 |
| October | 975,000 | 43,524 | 12 9 |
| November | 1,093,000 | 47,218 | 13 9 |
| December | 975,000 | 43,524 | 12 9 |
| Total for year | | 494,906 | |
| **1896** | | | |
| January | 460,000 | 20,535 | 7 5 |
| February | 349,000 | 14,574 | 5 11 |
| March | 368,000 | 16,416 | 6 2 |
| April | 447,000 | 19,311 | 7 3 |
| May | 492,000 | 22,204 | 7 10 |
| June | 521,000 | 22,528 | 8 2 |
| July | 535,000 | 23,882 | 8 4 |
| August | 694,000 | 30,989 | 10 1 |
| September | 824,000 | 35,620 | 11 4 |
| October | 757,000 | 33,774 | 10 9 |
| November | 809,000 | 34,934 | 11 3 |
| December | 519,000 | 23,172 | 8 2 |
| Total for year | | 297,939 | |
| **1897** | | | |
| January | 366,000 | 16,355 | 6 2 |
| February | 411,000 | 16,564 | 6 9 |
| March | 377,000 | 16,826 | 6 4 |
| April | 258,000 | 11,138 | 4 6 |
| May | 210,000 | 9,382 | 3 9 |
| June | 155,000 | 6,697 | 2 9 |
| July | 222,000 | 9,893 | 3 11 |
| August | 465,000 | 20,742 | 7 6 |
| September | 785,000 | 33,922 | 11 0 |
| October | 1,052,000 | 46,959 | 13 5 |
| November | 1,151,000 | 49,704 | 14 3 |
| December | 881,000 | 39,366 | 11 11 |
| Total for year | | 277,548 | |

| Month. | Mean Volume—Cub. Ft. per Min. | Monthly Totals—Millions of Cub. Ft. | Mean Depth on Nav. Chl. Bed. Ft. In. |
|---|---|---|---|
| **1898** | | | |
| January | 314,000 | 14,022 | 5 5 |
| February | 294,000 | 11,857 | 5 1 |
| March | 384,000 | 17,144 | 6 5 |
| April | 451,000 | 19,493 | 7 4 |
| May | 270,000 | 12,066 | 4 8 |
| June | 209,000 | 9,019 | 3 8 |
| July | 456,000 | 20,357 | 7 4 |
| August | 559,000 | 24,956 | 8 7 |
| September | 788,000 | 34,055 | 11 0 |
| October | 944,000 | 42,149 | 12 6 |
| November | 944,000 | 40,780 | 12 6 |
| December | 804,000 | 35,889 | 11 2 |
| Total for year | | 281,787 | |
| **1899** | | | |
| January | 527,000 | 23,531 | 8 3 |
| February | 196,000 | 7,903 | 3 0 |
| March | 151,000 | 6,761 | 2 8 |
| April | 275,000 | 11,874 | 4 9 |
| May | 278,000 | 12,414 | 4 10 |
| June | 294,000 | 12,719 | 5 1 |
| July | 547,000 | 24,421 | 8 6 |
| August | 880,000 | 39,299 | 11 11 |
| September | 975,000 | 42,127 | 12 9 |
| October | 939,000 | 41,911 | 12 5 |
| November | 652,000 | 28,179 | 9 8 |
| December | 526,000 | 23,480 | 8 3 |
| Total for year | | 274,619 | |
| **1900** | | | |
| January | 249,000 | 11,150 | 4 4 |
| February | 85,000 | 3,427 | 1 5 |
| March | 28,000 | 1,249 | 0 3 |
| April | 85,000 | 3,692 | 1 5 |
| May | 375,000 | 16,656 | 6 3 |
| June | 506,000 | 22,370 | 8 0 |
| July | 714,000 | 31,891 | 10 3 |
| August | 1,093,000 | 48,814 | 13 9 |
| September | 1,598,000 | 69,060 | 17 6 |
| October | 1,731,000 | 77,270 | 18 5 |
| November | 1,778,000 | 76,785 | 18 9 |
| December | 1,406,000 | 61,907 | 16 2 |
| Total for year | | 424,271 | |
| **1901** | | | |
| January | 467,000 | 20,917 | 7 6 |
| February | 214,000 | 8,628 | 3 9 |
| March | 50,000 | 2,232 | 0 9 |
| April | 24,000 | 1,037 | 0 0 |
| May | 28,000 | 1,250 | 0 3 |
| June | 212,000 | 9,158 | 3 9 |
| July | 373,000 | 16,662 | 6 3 |
| August | 428,000 | 19,137 | 7 0 |
| September | 596,000 | 25,750 | 9 0 |
| October | 880,000 | 39,198 | 11 11 |
| November | 1,135,000 | 49,144 | 14 1 |
| December | 1,102,000 | 49,208 | 13 10 |
| Total for year | | 242,321 | |

MORGAN GAUGINGS—*continued.*

| Month. | Mean Volume—Cub. Ft. per Min. | Monthly Totals—Millions of Cub. Ft. | Mean Depth on Nav. Chl. Bed. |
|---|---|---|---|
| **1902** | | | Ft. In. |
| January | 662,000 | 29,552 | 9 9 |
| February | 262,000 | 10,967 | 4 7 |
| March | 100,000 | 4,460 | 1 9 |
| April | 24,000 | 1,037 | — |
| May | 24,000 | 1,071 | — |
| June | 24,000 | 1,051 | — |
| July | 81,000 | 3,620 | 1 4 |
| August | 234,000 | 10,454 | 4 1 |
| September | 218,000 | 9,427 | 3 10 |
| October | 152,000 | 6,790 | 2 8 |
| November | 214,000 | 9,228 | 3 9 |
| December | 126,000 | 5,617 | 2 3 |
| Total for year | | 93,274 | |
| **1903** | | | Ft. In. |
| January | 94,000 | 4,206 | 1 8 |
| February | 105,000 | 4,227 | 1 10 |
| March | 24,000 | 1,051 | — |
| April | 24,000 | 1,037 | — |
| May | 120,000 | 5,357 | 2 1 |
| June | 342,000 | 14,771 | 5 10 |
| July | 538,000 | 24,012 | 8 4 |
| August | 832,000 | 37,142 | 11 5 |
| September | 1,088,000 | 47,004 | 13 9 |
| October | 1,206,000 | 53,867 | 14 8 |
| November | 1,338,000 | 57,785 | 15 8 |
| December | 1,371,000 | 61,207 | 15 11 |
| Total for year | | 311,666 | |
| **1904** | | | Ft. In. |
| January | 930,000 | 41,502 | 12 4 |
| February | 843,000 | 35,195 | 11 7 |
| March | 479,000 | 21,387 | 7 8 |
| April | 356,000 | 15,398 | 6 0 |
| May | 325,000 | 14,531 | 5 7 |
| June | 388,000 | 16,748 | 6 6 |
| July | 469,000 | 20,957 | 7 6 |
| August | 793,000 | 35,403 | 11 1 |
| September | 1,068,000 | 46,139 | 13 6 |
| October | 1,250,000 | 55,804 | 15 0 |
| November | 1,191,000 | 51,481 | 14 6 |
| December | 1,156,000 | 51,642 | 14 3 |
| Total for year | | 406,187 | |
| **1905** | | | Ft. In. |
| January | 601,000 | 26,849 | 9 1 |
| February | 233,000 | 9,404 | 4 1 |
| March | 104,000 | 4,641 | 1 10 |
| April | 60,000 | 2,618 | 1 0 |
| May | 217,000 | 9,677 | 3 10 |
| June | 407,000 | 17,596 | 6 9 |
| July | 554,000 | 24,712 | 8 7 |
| August | 892,000 | 39,822 | 12 0 |
| September | 1,304,000 | 56,333 | 15 5 |
| October | 1,582,000 | 70,632 | 17 5 |
| November | 1,221,000 | 52,702 | 14 9 |
| December | 1,090,000 | 48,679 | 13 9 |
| Total for year | | 363,725 | |

| Month. | Mean Volume—Cub. Ft. per Min. | Monthly Totals—Millions of Cub. Ft. | Mean Depth on Nav. Chl. Bed. |
|---|---|---|---|
| **1906** | | | Ft. In. |
| January | 1,049,000 | 46,840 | 13 5 |
| February | 271,000 | 10,932 | 4 9 |
| March | 226,000 | 10,087 | 4 0 |
| April | 458,000 | 19,766 | 7 5 |
| May | 550,000 | 24,541 | 8 6 |
| June | 649,000 | 28,057 | 9 7 |
| July | 859,000 | 38,354 | 11 8 |
| August | 1,149,000 | 51,306 | 14 2 |
| September | 1,678,000 | 72,488 | 18 1 |
| October | 2,083,000 | 92,973 | 20 7 |
| November | 2,486,000 | 107,392 | 22 8 |
| December | 2,714,000 | 121,164 | 23 10 |
| Total for year | | 623,900 | |
| **1907** | | | Ft. In. |
| January | 1,911,000 | 85,328 | 19 7 |
| February | 954,000 | 38,451 | 12 7 |
| March | 641,000 | 28,618 | 9 6 |
| April | 383,000 | 16,547 | 6 5 |
| May | 383,000 | 17,105 | 6 5 |
| June | 377,000 | 16,281 | 6 4 |
| July | 409,000 | 18,242 | 6 9 |
| August | 488,000 | 21,779 | 7 9 |
| September | 747,000 | 32,257 | 10 7 |
| October | 825,000 | 36,817 | 11 5 |
| November | 680,000 | 29,379 | 9 11 |
| December | 523,000 | 23,338 | 8 2 |
| Total for year | | 364,142 | |
| **1908** | | | Ft. In. |
| January | 347,000 | 14,985 | 5 11 |
| February | 275,000 | 11,505 | 4 9 |
| March | 100,000 | 4,464 | 1 9 |
| April | 280,000 | 12,117 | 4 10 |
| May | 389,000 | 17,372 | 6 6 |
| June | 425,000 | 18,370 | 7 0 |
| July | 420,000 | 18,752 | 6 11 |
| August | 535,090 | 23,887 | 8 4 |
| September | 672,000 | 29,035 | 9 10 |
| October | 872,000 | 38,928 | 11 10 |
| November | 966,000 | 41,726 | 12 8 |
| December | 650,000 | 29,037 | 9 7 |
| Total for year | | 260,178 | |

TABLE IV.—TOTAL DISCHARGE OF THE MURRAY RIVER FOR EACH OF THE YEARS, 1886 TO 1908 INCLUSIVE, AT MILDURA, AT THE EASTERN BOUNDARY OF SOUTH AUSTRALIA, AND AT MORGAN.

TOTAL DISCHARGE IN MILLIONS OF CUBIC FEET.

| | Year. | At Mildura. | At Eastern Boundary of South Australia. | At Morgan. |
|---|---|---|---|---|
| Low | 1886 | 236,991 | 348,763 | 317,094 |
| High | 1887 | 559,320 | 802,386 | 731,456 |
| Mean | 1888 | 354,263 | 552,011 | 503,289 |
| High | 1889 | 642,498 | 765,659 | 697,717 |
| High | 1890 | 516,461 | 1,169,586 | 1,067,007 |
| High | 1891 | 534,014 | 968,675 | 883,709 |
| Mean | 1892 | 359,477 | 562,138 | 513,024 |
| High | 1893 | 511,227 | 847,191 | 773,034 |
| High | 1894 | 750,123 | 1,047,278 | 955,087 |
| Mean | 1895 | 346,584 | 542,257 | 494,906 |
| Low | 1896 | 205,454 | 330,079 | 297,939 |
| Low | 1897 | 197,283 | 308,314 | 277,548 |
| Low | 1898 | 204,258 | 308,161 | 281,787 |
| Low | 1899 | 209,685 | 310,460 | 274,619 |
| Mean | 1900 | 354,303 | 472,977 | 424,271 |
| Low | 1901 | 210,394 | 271,221 | 242,321 |
| Minimum | 1902 | 56,244 | 102,588 | 93,274 |
| Low | 1903 | 215,003 | 342,792 | 311,666 |
| Mean | 1904 | 269,682 | 446,754 | 406,187 |
| Low | 1905 | 287,115 | 400,050 | 363,725 |
| High | 1906 | 560,543 | 686,209 | 623,900 |
| Low | 1907 | 228,677 | 400,510 | 364,142 |
| Low | 1908 | 178,286 | 286,164 | 260,178 |

| | | |
|---|---|---|
| Minimum year | 1 | |
| Other low years | 10 | Under 400,000 millions of cubic feet, at Morgan. |
| Mean years | 5 | From 400,000 to 600,000 millions of cubic feet, at Morgan. |
| High years | 7 | Over 600,000 millions of cubic feet, at Morgan. |
| Total | 23 | |

Adelaide, February, 1910.

S. M.

# APPENDICES.

## APPENDIX I.

### STATE RIVERS AND WATER SUPPLY COMMISSION.—PROVISION OF TANKS IN LONG LAKE WATERWORKS DISTRICT.

NOTICE TO OWNERS AND OCCUPIERS.

Pursuant to section 177 of the *Water Act*, 1905, notice is hereby given that the State Rivers and Water Supply Commission requires all owners or occupiers of lands within the Long Lake Waterworks District to make provision by dams or tanks for the storage on such lands of water supplied by the Commission for domestic and ordinary use and for watering cattle or other stock, that is to say:—

The total tank capacity to be provided on every block of 640 acres shall not be less than 2,000 cub. yds., and on every block of 320 acres shall not be less than 1,000 cub. yds. A block may be supplied by more than one tank, but in no case shall any tank be of less capacity than 1,000 cub. yds.

Every tank must have a depth of at least 12ft.

Every tank must be connected with the supply channel by properly constructed drains of sufficient capacity to take the full flow therefrom.

In future water will be run in each of the Commission's channels to fill tanks ONCE ONLY IN EACH YEAR, commencing on 1st July, 1909. Settlers will be notified of the date when water will be sent down the channels commanding their respective holdings.

By order,

Melbourne, 23rd March, 1909. ——— M. NALLY, Secretary.

To each owner or occupier.

NOTE.—Special attention is drawn to the necessity of providing a minimum depth of 12ft. for all tanks. This provision will be strictly insisted upon by the Commission. With a view of securing the best site for a tank the Commission recommends that before commencing to excavate the full size, a small trial shaft should be sunk to test the nature of the ground beneath.

## APPENDIX II.

### STATE RIVERS AND WATER SUPPLY COMMISSION.

BY-LAW No. 105.—GENERAL RATE.—LONG LAKE WATERWORKS DISTRICT.

The State Rivers and Water Supply Commission, in pursuance and in exercise of the powers conferred by the *Water Act*, 1905, doth hereby make the by-law following:—

1. The following general rate is hereby made under the provisions of section 62 of the *Water Act*, 1905, and shall be levied upon the occupiers or owners of all lands within the Long Lake Waterworks District, except within any Urban District thereof:—

For the supply of water for the domestic and ordinary use of persons dwelling upon such lands, and for watering cattle or other stock—

(1) Of all lands in the First Division, as shown colored red on a plan signed and sealed by the Commission and lodged at the office of such Commission at Melbourne, and authenticated copies of which are also lodged at the office of the Commission at Swan Hill, the office of the Municipality of Swan Hill at Swan Hill, and the post-office at Goschen—a rate of thirty-three pence in the pound of the ratable value of such lands.

(2) Of all lands in the Second Division, as shown colored green on the aforesaid plan—a rate of sixteen and one-half pence in the pound of the ratable value of such lands.

(3) Of all lands in the Third Division, as shown colored brown on the aforesaid plan—a rate of eight and one-fourth pence in the pound of the ratable value of such lands.

2. Such rate is made and shall be levied for the year beginning with the first day of July, 1909, and ending with the thirtieth day of June, 1910, and shall be payable on the fifth day of October, 1909, at the office of the said Commission at Swan Hill.

3. Such person or persons as the said Commission may from time to time appoint for that purpose shall be and is or are hereby authorised to demand, receive, collect, and recover the said rate.

4. For making and levying such rate the value of the lands set out in the valuation made, in accordance with the provisions of the *Water Act*, 1905, by F. Bassett, valuer, returned on the 28th day of November, 1906, and adopted by the said Commission on the 21st day of December, 1906, shall be deemed and taken

to be the ratable value of sueh lands unless altered or amended as provided by the said *Water Act*, 1905 and if so altered or amended then the net annual value of such lands set out in such altered or amended valuation.

The foregoing By-law was made by the State Rivers and Water Supply Commission on the sixth day of September, one thousand nine hundred and nine, and the common seal of the said Commission was hereunto affixed the twentieth day of September, one thousand nine hundred and nine, in the presence of—

ELWOOD MEAD, Chairman.
(Seal) WM. CATTANACH, Commissioner.
G. GARSON, Commissioner.

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Approved by the Governor in Council, 25th September, 1909.

F. W. MABBOTT, Clerk of the Executive Council.

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*Government Gazette*, 29th September, 1909, *Swan Hill Guardian*, 1st October, 1909. *Kerang New Times*, 1st Oetober, 1909. *Kerang Observer*, 2nd Oetober, 1909.

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[Note.—First Div.—Lands commandable by a branch from existing channel not exceeding one mile from nearest point of allotment. Second Div.—Lands commandable by a branch from existing channel not more than two and a half miles long. Third Div.—All lands not covered by above. Long Lake Act repealed by *Water Act*, 1905.]

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# APPENDIX III.

## PARTICULARS OF PUMPING PLANTS UNDER THE CONTROL AND MANAGEMENT OF THE STATE RIVERS AND WATER SUPPLY COMMISSION OF VICTORIA AT 5th AUGUST, 1909.

### NYAH PUMPING PLANT.

*Work Required.*—To deliver 1,500 cub. ft. per minute against a virtual head of 80ft.

*Plant.*—One triple expansion high speed Allen engine, of 450 revolutions per minute, and of 365 brake horsepower, with jet eondensers and Edwards' air pumps for 26in. vaeuüm, direct-coupled to a Smith-Michell patent two-stage centrifugal pump of 24in. delivery. Steam supplied by one under-fired multitubular boiler, 7ft. by 20ft., with 90 4in. tubes; and one Watkinson type superheater of 300 sq. ft. heating surface, capable of superheating the steam 150° to 200°.

*Working Boiler Pressure*, 150lbs. *Ratio of Work* to theoretical effect, as per maker's guarantee, 8·46lbs. of steam to one million ft.-lbs. of work. Actual use of plant just entered on.

### WHITE CLIFFS PUMPING PLANT.

This eonsists of two units, each of whieh is a duplicate of the plant at Nyah, the conditions varying only in the faet that the virtual head pumped against is 95ft.

The guaranteed ratio of work to theoretical effect is the same as at Nyah.

The plant has not yet been tested.

### SWAN HILL PUMPING PLANT.

*Work.*—To deliver 6,000 cub. ft. per minute against a virtual head of 18ft.

*Plant.*—One triple expansion high speed Allen engine, of 250 revolutions per minute, and of 300-brake horsepower, with jet condenser and Edwards' air pumps, as at Nyah, direct-coupled to two 39in. (suction and delivery) low lift centrifugal pumps, each to lift 3,000 cub. ft. per minute of the total required. Boilers as at Nyah.

*Guaranteed Ratio of Work* to theoretical effeet, 9·73lbs. of steam to one million ft.-lbs. of work.

The plant has not been in use for a period sufficiently long to establish the value of the work done.

### KOONDROOK PUMPING PLANT.

This is an exact duplicate of the plant at Swan Hill, and is subject to a like guarantee. It is now in coursc of erection.

### COHUNA PUMPING PLANT.

There is here a plant, now in use about 18 years. It delivers 6,000 cub. ft. per minute against a virtual head of 16ft. It is considered somewhat obsolete.

The new plant, about to be erected, eonsists of two units, each identical with the plant at Swan Hill; except that ejector condensers have been substituted for jet condensers and air pumps. This is with a view to economy.

The guaranteed ratio of work to theoretical effect is 9·73lbs. of steam to one million ft.-lbs. of work.

# APPENDIX IV.

## STATE RIVERS AND WATER SUPPLY COMMISSION.

### LONG LAKE WATERWORKS DISTRICT.—PUMPING PLANT.

This installation is for water for stock and domestic supply only, not for irrigation. It has been in use for five years.

It consists of a Reidler pump, driven by a cross-compound condensing engine, with Twis-Corliss valves. The boiler is 16ft. by 6ft. 6in., of type similar to that at Nyah, working at 120lbs. pressure.

Maximum capacity of plant, 3,000,000gals. day = 330 c.f.m., through rising main 7¼ miles long, 18in. dia., against total virtual head of 200ft. (static 120ft., friction 80ft.)

Rising main, 7¼ miles, 18in. dia. spiral riveted steel, 10 to 14 gauge, according to pressure head.

Approximate cost (installed)—Pumping plant, £5,000; rising main, £11,000.

Supply is obtained from Long Lake and Lake Boga (now connected). These lakes are filled yearly by overflow from Little Murray River.

Under ordinary working conditions a constant volume (24 hours daily) is lifted, against a varied pressure head from 80ft. to 180ft., according to position of the offtakes to channels along the rising main, to the high country in the vicinity of Goschen. The channels take directly off the pipe line. The system throughout is designed to carry the full discharge of the pumping plant, viz., 300 c.f.m.—the stream being undivided. Channels throughout, 3ft. bed width, 1 to 1 side slopes; grades—maximum, 4ft. per mile; minimum, 9in. per mile; running depth, working conditions, 1ft. 9in. to 2ft.

The channels are laid out so that a branch will be within one mile of each block. The landholder is expected to make the required connection.

| | |
|---|---|
| Full area expected to be served by Long Lake plant, approximately.. | 700 square miles. |
| Average put into tanks on each square mile ..... | 2,000 cub. yds. |
| Time necessary to supply once around area in cooler months of year.. | 5 to 6 months. |
| Approximate cost of channel system on above stated basis ..... | £60 to £70 per square mile. |

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# APPENDIX V.

## ESTIMATE OF COST OF NAVIGATION WORKS IN SOUTH AUSTRALIA.

### CONSTRUCTION OF WEIR AND LOCK, IN ACCORDANCE WITH TYPE DESIGN.

| | £ |
|---|---|
| 1. Coffer-dams and other temporary works ..... | 2,000 |
| 2. Bailing and pumping during construction ..... | 750 |
| 3. Excavation—23,000 cub. yds. @ 2/- ..... | 2,300 |
| 4. Cement concrete in foundations of abutment, weir, curtain wall, and lock—16,500 cub. yds. @ 40/- ..... | 33,000 |
| 5. Reinforcement of concrete, steel bars in place—70 tons @ 120/- ..... | 420 |
| 6. Hard filling in abutment—600 cub. yds. @ 5/- ..... | 150 |
| 7. Stone-facing on bank and abutment—600 sup. yds. @ 30/- ..... | 900 |
| 8. Movable weir, including trestles, gangway, wickets, &c. ..... | 11,000 |
| 9. Lock gates complete—2 pairs @ £500 ..... | 1,000 |
| 10. Lock culverts with valves and gearing—2 @ £50..... | 100 |
| 11. Sundries..... | 4,000 |
| 12. Provision for flood risks, &c. ..... | 8,000 |
| 13. Lock-keeper's cottage, store, &c..... | 500 |
| 14. Contingencies, engineering, supervision, &c. ..... | 9,618 |
| Total—weir and lock ..... | £73,738 |

### GENERAL ESTIMATE.

| | £ |
|---|---|
| 1. Slack water navigation works (each weir and lock)—6 @ £73,738..... | 442,428 |
| 2. Snagging and clearing channel ..... | 5,000 |
| 3. Removing shoals, &c. ..... | 10,000 |
| 4. Constructing training walls and defence works ..... | 13,000 |
| 5. Embankments for isolating back-waters, lagoons, and ana-branches ..... | 12,000 |
| Total navigation works in South Australia ..... | £482,428 |

# APPENDIX VI.

## ESTIMATE OF COST OF THE GOOLWA TO VICTOR HARBOR CANAL; BASED ON THE APPROXIMATE QUANTITIES GIVEN BY THE PUBLIC WORKS DEPARTMENT.

| | £ |
|---|---|
| 1. Excavation in earth, Goolwa to Middleton Creek, 1,260,000 cub. yds. @ 8d... | 42,000 |
| 2. Excavation in earth, Middleton Creek to Victor Harbor, 4,186,000 cub. yds. @ 10d. | 174,417 |
| 3. Excavation in rock, Middleton Creek to Victor Harbor, 500,000 cub. yds. @ 2s. 6d. | 62,500 |
| 4. Shifting railway line, 1 mile 7 furlongs (Public Works estimate) ..... | 16,000 |
| 5. Road bridges, with approaches, 4 ..... | 4,500 |
| 6. Bridge for railway and road ..... | 4,000 |
| 7. Railway bridge ..... | 3,000 |
| 8. Fencing, gates, &c. ..... | 1,250 |
| 9. Protecting slopes ..... | 4,000 |
| 10. Protective works at Victor Harbor outlet ..... | 14,000 |
| 11. Tide lock at outlet ..... | 15,000 |
| 12. Land, contingencies, supervision, and interest (Public Works estimate) ..... | 115,063 |
| Total, Goolwa to Victor Canal ..... | £455,730 |

Adelaide, February, 1910. S. M.

1905 1906 1907 1908

P.P. Nº 29 (I.)

# MURRAY RIVER WATERS.

## SHEET Nº1, MONTHLY DISCHARGES AT MORGAN, AT THE EASTERN BOUNDARY OF SOUTH AUSTRALIA, AND AT MILDURA.

SCALES { HORIZONTAL – 1.20 INCHES PER YEAR
VERTICAL – 1 INCH PER 5 FT OF DEPTH.

S. Stuart Murray
M. Inst. C.E.
Dec: 1909.

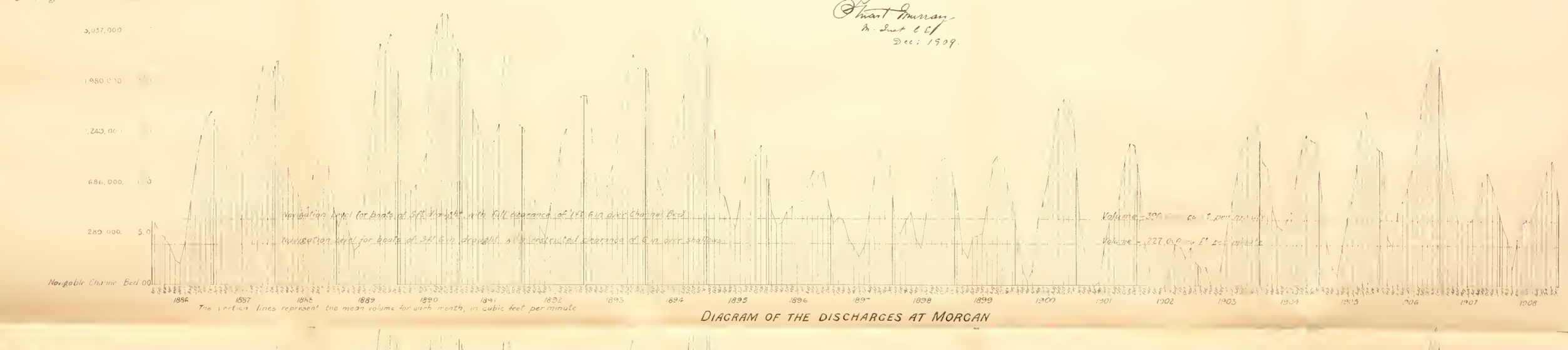

Volumes in cubic ft per minute, and corresponding depths on Navigable Channel Bed
3,037,000
1980 0 10
1,249,00 [illegible]
686,000. 7.5
289 000. 5.0
Navigable Channel Bed 00
Navigation level for boats of 5ft draught, with full clearance of 1ft 6in over Channel Bed
Navigation level for boats of 3ft 6in draught, with restricted clearance of 6in over shallows
Volume = 390 [illegible] cu ft per minute
Volume = 227,000 cu ft per minute
1856 1887 1888 1889 1890 1891 1892 1893 1894 1895 1896 1897 1898 1899 1900 1901 1902 1903 1904 1905 1906 1907 1908
The vertical lines represent the mean volume for each month, in cubic feet per minute

DIAGRAM OF THE DISCHARGES AT MORGAN

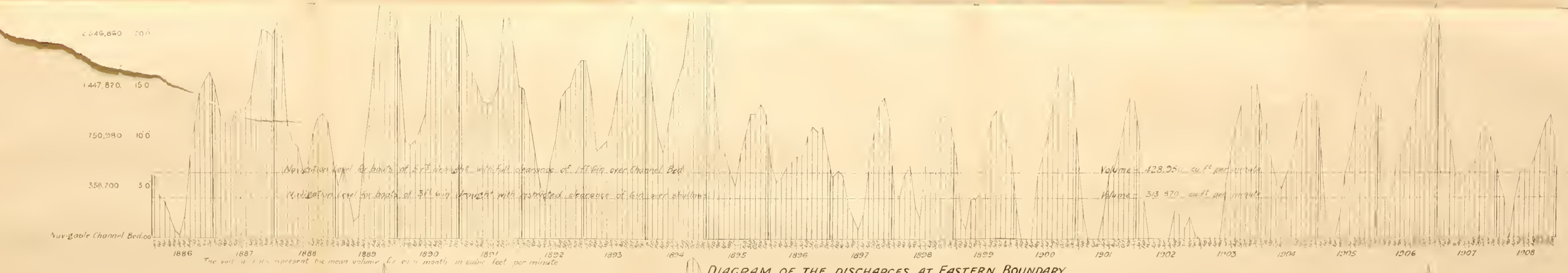

2 846,860 20.0
1 447, 870. 15 0
750,980 10.0
358,200 5 0
Navigable Channel Bed 00
Navigation level for boats of 5ft draught, with full clearance of 1ft 6in over Channel Bed
Navigation level for boats of 3ft 6in draught, with restricted clearance of 6in over shallows
Volume = 428,950 cu ft per minute
Volume = 313 870 cu ft per minute
1886 1887 1888 1889 1890 1891 1892 1893 1894 1895 1896 1897 1898 1899 1900 1901 1902 1903 1904 1905 1906 1907 1908
The vertical lines represent the mean volume for each month, in cubic feet per minute

DIAGRAM OF THE DISCHARGES AT EASTERN BOUNDARY

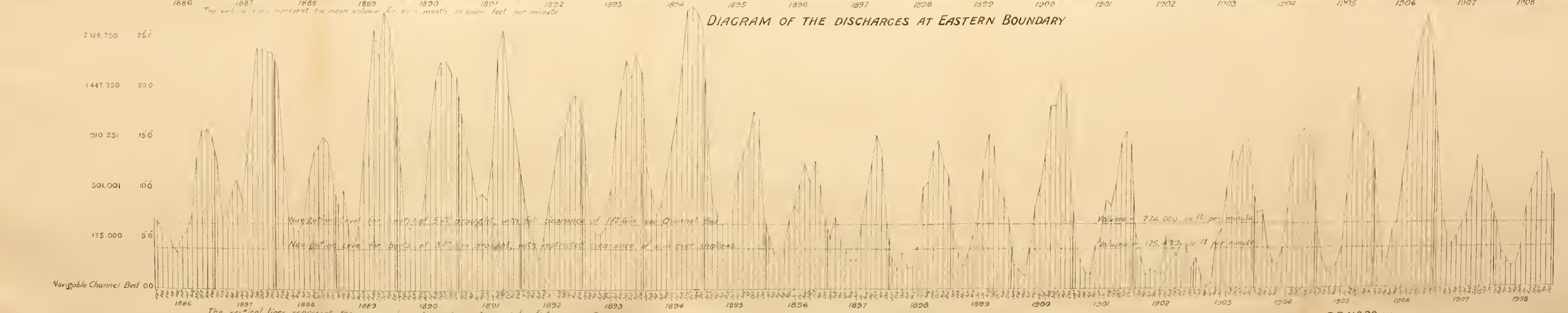
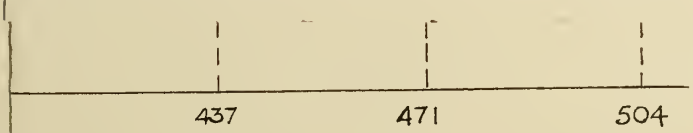

2 128,750 25.0
1 447,750 20 0
910 251 15.0
501,001 10.0
175.000 5.0
Navigable Channel Bed 00
Navigation level for boats of 5ft draught, with full clearance of 1ft 6in over Channel Bed
Navigation level for boats of 3ft 6in draught, with restricted clearance of 6in over shallows
Volume = 274 000 cu ft per minute
Volume = 125,433 cu ft per minute
1886 1887 1888 1889 1890 1891 1892 1893 1894 1895 1896 1897 1898 1899 1900 1901 1902 1903 1904 1905 1906 1907 1908
The vertical lines represent the mean volume for each month, in cubic feet per minute

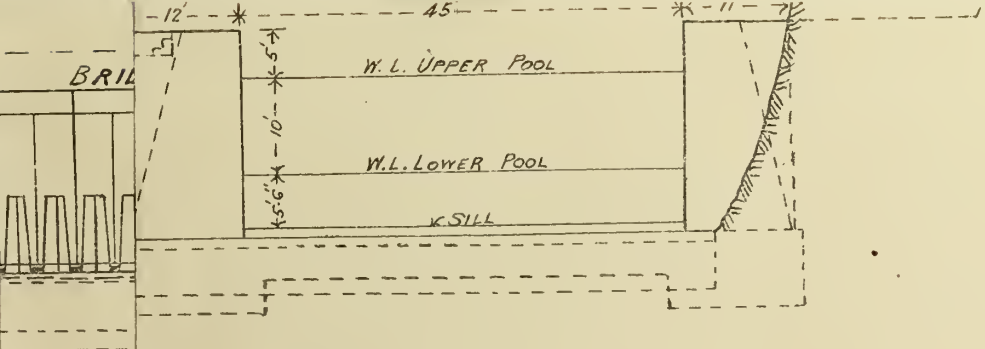
DIAGRAM OF THE DISCHARGES AT MILDURA.

P.P. Nº 29 (1)




River debouchement
— Miles.

N. S. WALES
VICTORIA
L. VICTORIA
MORGAN
WEIR & LOCK Lift 10 Ft
RIVER MURRAY
Overland Corner
Renmark
L. Bonnet
Moorook
Berri Beri
Loxton
Blanche Town
Portee
Eudunda
Kapunda
Railway
Line
Rosewerthy
Crawler
Basin
APPROX POSITION WEIR & LOCK
Swan Reach
South Australian Railways
Port Adelaide
ADELAIDE
Glenelg
Railway
Mannum
Walker's Flat
Murray River
Mt. Barker
MURRAY BRIDGE
Tailem Bend
Strathalbyn
Mulgundawa
Wellington
Milang
LAKE ALEXANDRINA
Goolwa
CANAL
Port Elliot
Victor Harbor
ENCOUNTER BAY
LAKE ALBERT
Meningie
The Coorong
GULF ST VINCENT
Boundary
Line
Railway
Mildura
Wentworth
Darling River Junction
Euston
Robinvale
Piangil
Swan Hill
Kerang
Echuca
Cohuna
Gunbower
Koondrook
Barham
Moulamein
Tooleybuc
Kulkyne
Nyah
Woodenbridge
Kerang
Swan Hill
Piangil
Robinvale
Euston
Mildura
Wentworth
Darling River Junction
Renmark
Paringa
Loxton
Berri
Moorook
Overland Corner
Waikerie
Morgan
Blanchetown
Swan Reach
Murtho
Chowilla
Mooleyuk Bend
Waikerie
Overland Corner
Berri Beri
Moorook
Loxton
Paringa
Renmark




ELEV

SHEET Nº 3

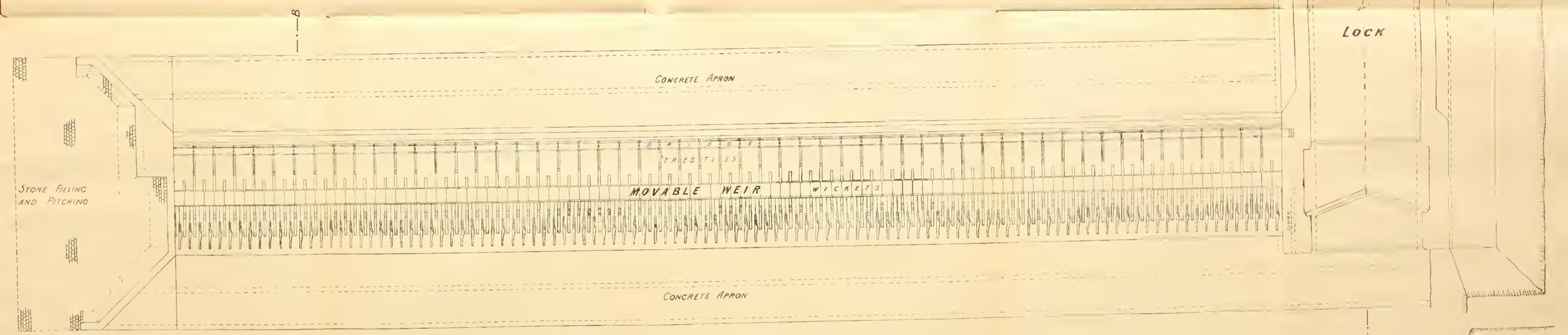
# MURRAY RIVER WATERS

## SLACK WATER NAVIGATION WORKS

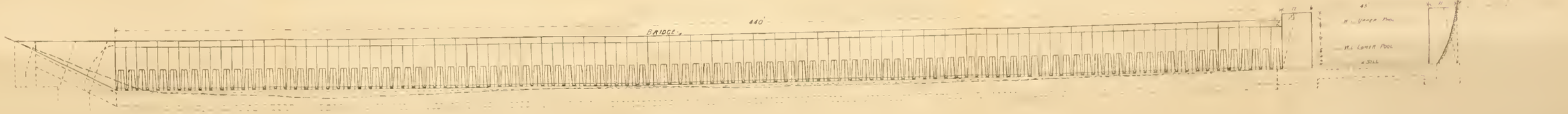
## TYPE DESIGN OF MOVABLE WEIR AND LOCK

SCALE - 20 FEET TO AN INCH

Stuart Murray
M. Inst. C.E.
Feb: 1910-

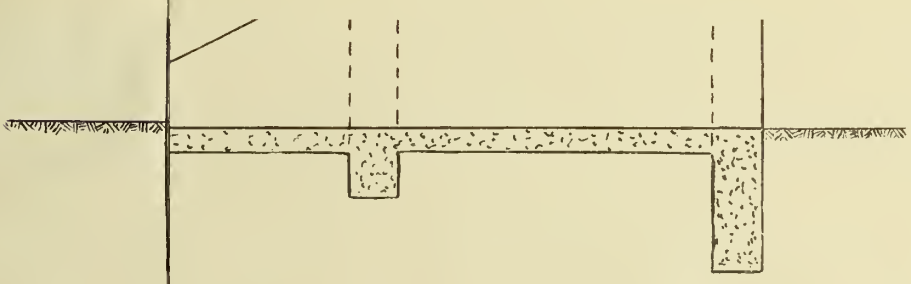


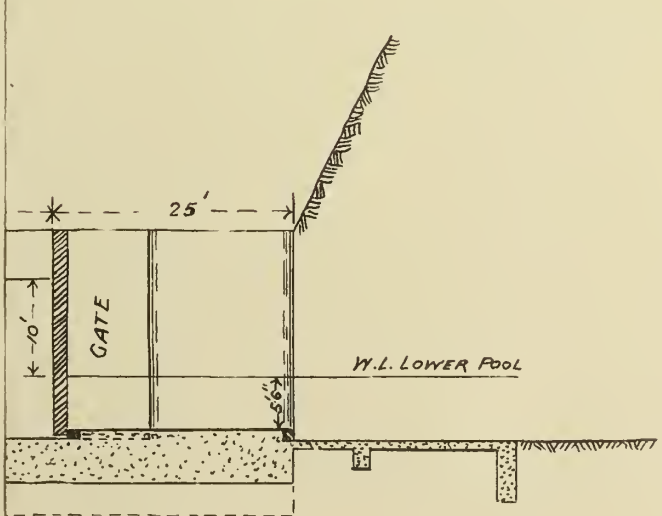

GENERAL PLAN




ELEVATION

P.P Nº 29 (3)




25'
10'
GATE
W.L. LOWER POOL
3.5'

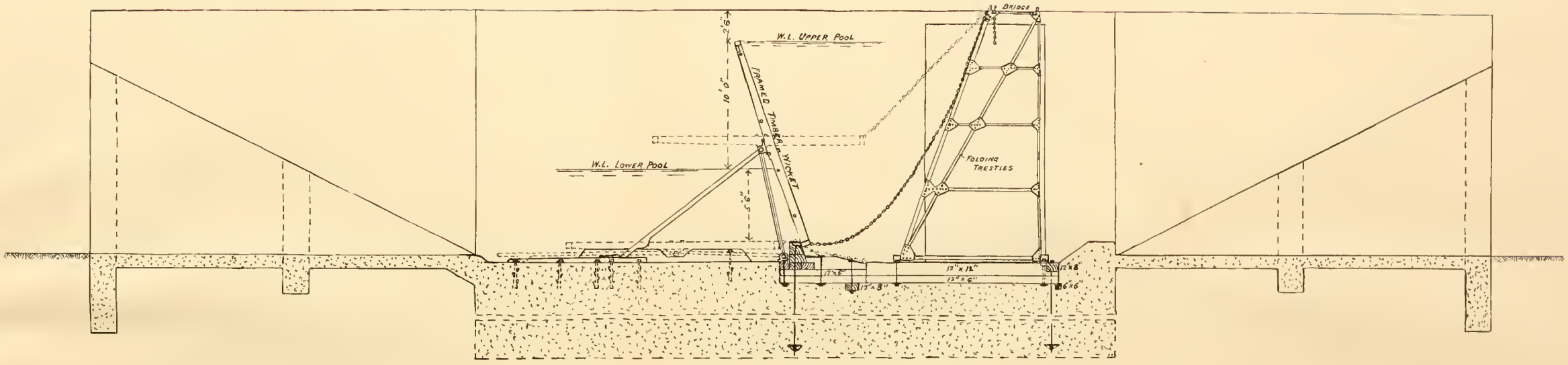
# MURRAY RIVER WATERS

SHEET Nº 4

## SLACK WATER NAVIGATION WORKS

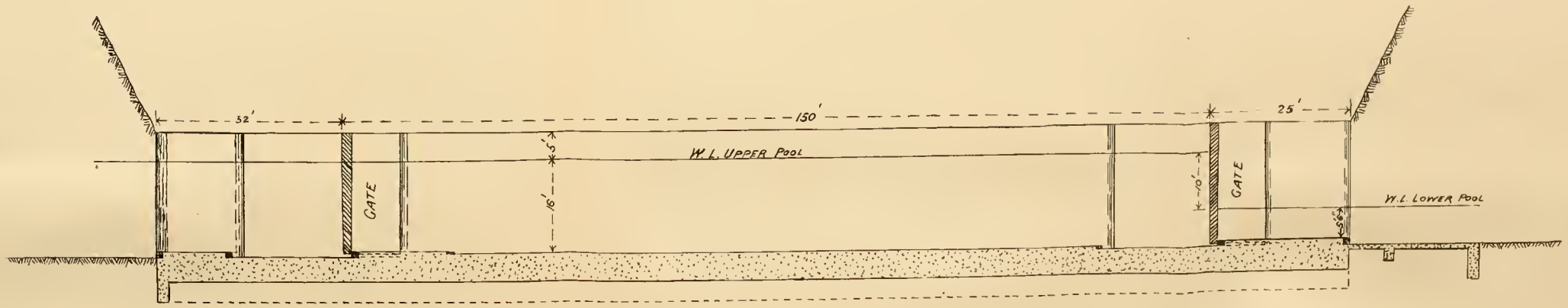
## DETAILS

Stuart Murray
Mr-Inst. C.E.
Feb: 1910.




SECTION A-B, THROUGH NAVIGATION WEIR.
ABUTMENT IN ELEVATION.

SCALE - $\frac{1}{8}$ INCH = 1 FOOT.




P.P. Nº 29(4)

LONGITUDINAL SECTION C-D OF LOCK
AND ELEVATION OF LAND WALL
SCALE - 20 FT TO AN INCH.

SURVEYOR GENERAL'S OFFICE ADELAIDE A Faughan Photo-Lithographer

3 0112 105328030